LOS ALAMOS NATIONAL LABORATORY

ANNUAL REPORT TO THE REGENTS UNIVERSITY OF CALIFORNIA

S. S. HECKER • DIRECTOR

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Los Alamos
NATIONAL LABORATORY

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PROFILE

Established in 1943 as Project Y of the Manhattan Engineer District, Los Alamos National Laboratory's original mission was to develop the world's first atomic bomb. Today, Los Alamos is a multidisciplinary, multiprogram laboratory of the United States Department of Energy (DOE). The University of California has managed the Laboratory since its beginnings in 1943. An important consequence of this management is the Laboratory's commitment to maintaining the tradition of free inquiry and debate that is essential to any scientific undertaking.

The Laboratory's original mission to design, develop, and test nuclear weapons has broadened and evolved as technologies, U.S. priorities, and the world community have changed. Today, we support our core mission, *reducing the global nuclear danger*, with the technical competencies developed for our national security and other programs. These competencies in turn allow us to contribute to civilian and conventional defense needs where our ability to perform large-scale, interdisciplinary research and development gives us a competitive advantage. We use partnerships with industry and universities to increase the effectiveness of our own work and to help us learn from others. In all our programs, we continue to maintain an intellectual environment that is open to new ideas. In addition, we are committed to ensuring that all our activities are designed to protect employees, the public, and the environment.

DIRECTOR'S STATEMENT

Siegfried S. Hecker, Director

As I prepare to turn the leadership of the Laboratory over to my successor, it is appropriate that I reflect on the changes that have occurred at the Laboratory and in the world where we do our work. The last twelve years have certainly seen drama and change; indeed, revolution is not too strong a term. When I accepted responsibility for the Laboratory, the nation was in the midst of a major weapon buildup, including the design and testing of several new nuclear weapon systems. Within five years the Soviet Union, the entity that had driven so much of our work for the past forty years, was no more. Today, we are committed to the idea that nuclear testing is a thing of the past; we are working to ensure the orderly reduction of nuclear weapon systems in the world; and we are working with our former adversaries in Russia to help them do the same.

No event so exemplifies the changes in the world of nuclear weapons as my jogging on the streets of the secret city of Arzamas-16, the Russian Los Alamos, in February 1992, barely two months after the collapse of the Soviet Union. Arzamas remained until very recently a city like wartime Los Alamos, one that the government did not admit existed. The greatest single international security danger the United States faces today is the rapid deterioration of the Russian nuclear weapon enterprise. I had occasion to witness the stress on the Russian nuclear enterprise during my visits to Russia in 1992, 1994, and 1996.

It was clear early on that the Russians had never deployed modern nuclear safeguards to protect their nuclear materials. They depended only on guards, guns, and fences. As the Soviet Union began to deteriorate, their methods were no longer adequate. On the basis of my first visit and the able support of former Deputy Secretary of Energy Charles Curtis, we set up an effective laboratory-to-laboratory program with the former nuclear weapon institutes. The program is doing much to contain the potential spread of nuclear weapon knowledge and materials. Today, we have begun the process of placing former Soviet nuclear weapon material under modern safeguards, and we are working closely with our colleagues on scientific collaborations that benefit both countries. Much progress has been made, but much remains to be done.

This period has also seen two other dramatic changes that have altered the Laboratory in profound ways. The 1980s saw a revolution in the way business does business—the quality revolution. Although we were late in realizing the effect this revolution would have on our operations, we finally saw the light and are working to incorporate quality concepts into everything we do. The Laboratory is moving forward by learning from the best the business world has to offer—from Motorola, from AT&T, and from Milliken. However, we are not a business in the strictest sense; we are a government operation, and we must adapt quality principles from business to the government setting. This is not easy, and we are therefore engaged in a struggle to redefine the relationship with our sponsors as one that will allow us to work in the most cost-effective way possible.

The 1980s also saw a revolution in the way the public perceives the operations of government. In 1984 a court decision held that the Y-12 plant at Oak Ridge, Tennessee, was subject to the Resource Conservation and Recovery Act and enforcement by the Environmental Protection Agency and the state of Tennessee. In the wake of this decision, a number of states challenged the Department's assertion of sovereign immunity, and over time all major environmental statutes have been amended to explicitly require compliance by federal agencies and their contractors, including the Laboratory. The public now expects us to abide by all environment, safety, and health legislation. Indeed, because of the nature of our work, we are held by many to a higher standard. The Department and the Laboratory can no longer respond that our work is too important to national security for public scrutiny, and as a public institution, we must ensure that we merit the public's trust.

Each of these revolutions has had profound implications for the work we do and the way we do that work. The challenge for the future is to be ready for changes that, like those of the last twelve years, cannot really be foreseen. I believe that management by the University of California has been crucial to the success of the Laboratory in facing these changes, and I would like to reflect on how that success came about.

J. Robert Oppenheimer, in his farewell address to the Association of Los Alamos Scientists on November 2, 1945, spoke of the invention of nuclear weapons as "not only a great peril, but a great hope." He realized at the time that while the invention carried risks, it also carried the possibility of bringing about "those changes which are needed if there is to be any peace." Today, more than fifty years after Oppenheimer's words were spoken, they have come true. The Berlin Wall fell in 1989; Boris Yeltsin climbed on top of a Soviet tank in August 1991 to halt an overthrow of the Soviet government; and then on Christmas day, 1991, the Soviet Union was dissolved, crushed under the weight of nearly seventy-five years of communism. The Cold War with its threats and tensions is over, and the dramatic arms reduction agreements between the United States and Russia are ushering in a new period of hope for the world.

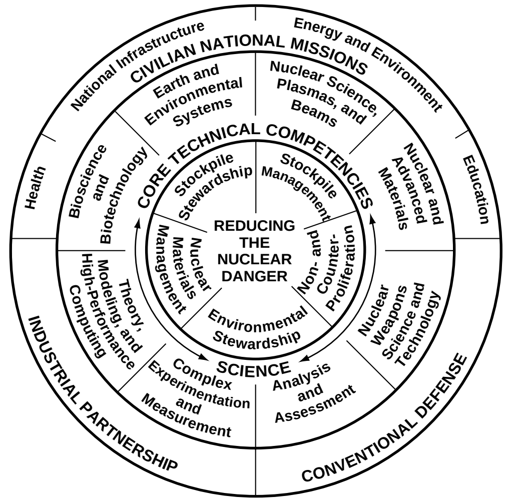
More than any other event, the end of the Cold War and the associated arms race with the Soviet Union have changed the Laboratory. Where we once worked with a massive production complex to design and develop new nuclear weapons, we are now the core of the nuclear weapon program, even taking on some of those production responsibilities. The immediate demand from the American people was for a *peace dividend*, a reduction in the military budgets that had fueled the arms race. Steadily declining budgets became a reality, and it was largely through the efforts of the University of California that we were able to absorb budget cuts through early retirement incentives, without the disruptions that large-scale reductions in force would have produced. In another way the Laboratory's traditions and the University's emphasis on excellence in science also helped us weather the reductions. We knew that whatever national priorities emerged, quality science would have a role that would allow us to serve the nation's changing needs.

The invasion of Kuwait by Saddam Hussein in 1990 and the subsequent Desert Storm operation reminded the American people and the world that we were not finished with tyrants. The subsequent investigations in Iraq that brought to light an extensive and sophisticated nuclear weapon program reminded everyone that the nuclear genie was out of the bottle, that nuclear weapons and, in particular, deterrence still had a place in world affairs. Nevertheless, in September 1992 President Bush declared a moratorium on nuclear testing, and in 1995 President Clinton announced his intention to seek a “zero-yield” Comprehensive Test Ban Treaty, which he signed in September 1996. President Clinton hailed it, along with the Senate’s ratification of the second of the Strategic Arms Reduction Treaties and the indefinite extension of the Nonproliferation Treaty, as the cornerstones of a new era in world security.

As these events unfolded, the Department and the Laboratory were struggling to redefine their roles. The Task Force on Alternative Futures for the DOE Laboratories (Galvin Task Force) in 1994 helped focus our attention, and we were able to articulate a clear and compelling mission for the Laboratory in this emerging context. The role of the University, particularly that of the national security panel of the President’s Council in this proceeding, was extremely important. The possibility that the laboratories could have succumbed to internecine squabbling was never far from the surface, and the University’s strong belief in the role of the laboratories as public servants was important in keeping the tone of the discussions at an appropriate level.

In response to the inquiries of the Galvin Task Force and the evolving mission of the nuclear weapon program, we focused our attention on what the Laboratory had to offer the nation as we looked to the future. We knew that whatever changes were coming in the long term, we still had to provide for the continued safety, security, and effectiveness of the weapons that remained, including an adequate supply of tritium for the remaining warheads. We also must help to ensure that the proliferation of weapons of mass destruction, still a real threat, can be detected and countered, if necessary. In particular, we must work with our former adversaries in Russia to ensure that the weapons, the specialized knowledge, and the materials that both nations worked so hard to produce do not fall into the wrong hands. We must ensure that the long-term disposition of nuclear materials is consistent with environmental preservation and nonproliferation goals, and we must clean up the legacy of the fifty-year development history of the nuclear weapon complex. These tasks form the core of the Laboratory’s mission—*reducing the global nuclear danger*.

While recognizing that our central mission is compelling, we also understand that it is not sufficient. We cannot perform this mission unless the Laboratory remains a scientific institution of the first rank. For the nation and indeed the world to have confidence that the U.S. stockpile is safe, secure, and reliable, particularly in the absence of the nuclear testing that provided tangible evidence of the stockpile’s power, we must also continue to contribute to national needs in areas where our scientific and technical capabilities are more transparent. By participating in the nation’s broader scientific enterprise, we can contribute to the solutions of national problems and underpin the Laboratory’s national security role at the same time. Work in support of conventional defense and civilian national goals



Los Alamos National Laboratory's central mission—reducing the global nuclear danger—requires the maintenance of core technical competencies that also contribute to civilian and other defense needs of the nation.

in energy and the environment, health care, space, and national infrastructure contributes to our reputation for excellence in science and technology and thereby increases confidence in our ability to carry our national security responsibilities.

Much of this work will be done in partnership with other entities. Basic and applied research will involve collaborations with the university community, demonstrating to all that we equal the best in the nation. In this we benefit substantially from our association with the University of California, the premier research institution in the nation, both in direct collaborations and in the visibility that association gives us within the university community. Other work, including a substantial portion of our national defense activities, will be done in partnership with industry. As we take on a limited role in manufacturing nuclear weapon components for the nation, we must ensure that we learn from the best in industry how to conduct those operations. Collaborations assist us directly by providing the know-how to accomplish the Laboratory's mission and indirectly by helping to recruit the best talent the nation has to offer, so that our traditions of excellence can continue.

Our mission is supported by eight core competencies: nuclear science, plasmas, and beams; nuclear and advanced materials; nuclear weapon science and technology; analysis and assessment; complex experimentation and measurement; theory, modeling, and high-performance computing; bioscience and biotechnology; and earth and environmental systems. The core competencies, in turn, provide the basis for our selective participation in civilian national missions, conventional defense research and development, and industrial partnerships. Work in these areas serves other important national needs while providing critical support to our central mission by strengthening and maintaining the core competencies. Thus, *reducing the global nuclear danger* is an effective shorthand for our mission, but it requires understanding the competencies needed to fulfill that mission and how they will be supported.

In collaboration with the weapon laboratories, the Department has responded well to the changing national security situation. The resulting stockpile stewardship and management plan is a coherent and focused view of the nation's needs with respect to the nuclear weapon stockpile. The laboratories are working closely with the Department to successfully implement the stockpile stewardship and management plan. Under the plan, the directors of the laboratories have the awesome responsibility—by Presidential Directive—of certifying annually that the weapons remaining in the stockpile are safe and reliable. The challenge is daunting, but it has helped to rejuvenate the scientific underpinnings of the Laboratory. Although we have concerns about the availability of adequate resources to do the job of certifying the stockpile now and laying the proper foundation for certifying it two decades from now, we are optimistic that the Administration and Congress both will support this vital national program.

The nuclear weapon laboratories' mission of stockpile stewardship and management is therefore inherently governmental. It also involves potentially astronomical risks and is often unpopular on campus or with the public. The government has recognized in the past that inherently governmental functions require special and creative contracting vehicles. The government-owned, contractor-operated (GOCO) partnership that emerged from that recognition allowed the laboratories to attract the scientific and management talents not typically available to the government. The partnership enlisted the talents of world-class organizations such as the University of California and AT&T Bell Laboratories to serve the government under a no-profit, no-loss operating principle as a public service. In essence, the employees of these organizations were an extension of the government, conducting an inherently governmental function in the best interest of the nation.

In response to perceived abuses of contracting procedures, the Department is attempting to shift the risks and liabilities of inherently governmental functions to the laboratory contractors through what it calls *contract reform*. This is the wrong approach and has endangered the very foundation of the contracting partnership that has been so successful for more than fifty years in providing the nation's nuclear deterrent. This is not to suggest that the government should not set the standards of performance. A performance-based GOCO partnership, in which the government sets the standards and then measures the performance of the contractors in terms of outcomes should be the goal. Applying the concepts of total quality management, which have revolutionized the business world in the last two decades, can revitalize the GOCO partnership. However, the application of quality principles to the partnership requires trust, and the government finds it difficult to trust its contractors.

We must continue to work toward improving the quality and productivity of the Laboratory if we are to continue to serve the nation as we have in the past. Although we have made some gains, the Department has not followed through with productivity improvements of its own. We cannot do this alone; our productivity gains cannot be achieved without the application of quality principles to the Department as well. To provide a quality product, we will require the trust of our sponsor and landlord, the Department of Energy. If the Department's oversight is excessive, we will continue to expend too much effort responding to that oversight, and we will be less productive. The Department must trust us to do a job effectively and efficiently. To be sure, they must measure and verify our performance; that is their appropriate role, but they can do this with less burdensome oversight.

The revolution in public expectations for accountability by government facilities and operations has added to the complexity of managing the Laboratory. For most of the Cold War, we focused on our product: the science and technology needed to develop the nation's nuclear arsenal. Scrutiny of our operations and their impact was confined to the Department, and the Laboratory was shielded from public scrutiny in the name of national security. The emergence of direct accountability to public entities for our environmental and safety performance resulted in a difficult transition. We are confident that our record shows that we have been responsible stewards of the environment. At the same time, we are not widely perceived by the public to meet the standards of accountability that would place us in a position of trust.

Establishing a constructive public interface, like the quality revolution, is an evolving situation. In the safety arena, we have had a difficult six years since the Tiger Team, struggling with rapidly changing DOE orders, directives, rules, and checkers and now focusing on what we should have started with, an integrated safety management system that puts the emphasis where it belongs, on the safe behavior of our staff, both on the job and at home. We are confident that this is the right road to travel and, with a quality approach, that it will take the Laboratory to our destination of an injury-free workplace.

In dealing with the environmental legacy of our past operations and with our activities in environmental stewardship, the future is less clear. We have been completely open about our past activities, particularly with respect to human experimentation with plutonium (see the discussion on the human studies project under "Bioscience and Biotechnology"), and we are committed to public scrutiny and participation so that we can earn the public's trust. This has been difficult. A citizen's lawsuit, filed by the Concerned Citizens for Nuclear Safety in Santa Fe under the Clean Air Act, has resulted in a consent decree mandating an independent audit of our compliance with the Federal Facility Compliance Agreement with the Environmental Protection Agency. We have not yet earned the public trust, but we have taken steps in the right direction. At the same time, we are beginning to develop a strong working relationship with the four neighboring Indian pueblos. By working together on issues of mutual concern, particularly environmental issues, we can begin earning the trust of those communities. The assistance of the University's Environment, Safety, and Health Panel has been very helpful in safety and environmental areas.

In 1993 President Bill Clinton visited Los Alamos, touring various technical sites with Laboratory Director Sig Hecker.

We must also be responsible corporate citizens. With the help of the University, we have also made great progress in this area. Opening the University of California Northern New Mexico office was a sound step. We have established the Los Alamos Foundation to enable the Laboratory to have a philanthropic presence in northern New Mexico; we will concentrate the work of this foundation on education and community development—efforts that will support the Laboratory in the long run, as well as the individuals and communities that will benefit directly. We have also added new features to our subcontracting activities, requiring major subcontractors to bring new business, not related to the Laboratory, to northern New Mexico. These actions will do much to foster economic development in the region and help diversify the economy.

We are thus making progress in improving our relationship with the communities that depend on the Laboratory. I am sure that our efforts in regional economic development and diversity, an enhanced corporate presence by the University, careful environmental stewardship, and a safe workplace will eventually lead to greater public confidence in everything we do.

Keeping our Laboratory first rate and making it attractive to the best talent is not easy today, but we cannot afford to take chances—the consequences of failure are too great. I firmly believe that we can attract the best talent only if we maintain our Laboratory as a first-rate scientific institution, with quality science and technology, quality operations, and a responsiveness to neighboring communities that exemplifies the best of corporate citizenship. Establishing a renewed partnership between the government and the University of California, founded in trust and public service, is the only way the Laboratory can succeed.

As I leave the Directorship, I look back on great accomplishments by a great Laboratory, based the collective excellence of its staff. At the same time, I leave some works in progress. Science-based stockpile stewardship is still unproved, but we must achieve its ends. The quality journey is not yet finished, and we do not yet have the public trust our mission deserves and requires. Nevertheless, we have served the nation well in these twelve years, and I have confidence that the future is bright for continued public service.

A Different Country

I'd like to try to assess, to a first approximation, fifty years along, what happened as a result of the work you did here, and what it meant. I'd like to remind you of something altogether more remarkable: that you changed the world. You changed the world irrevocably, and short of the destruction of human memory there will be no changing it back. That's certainly what Robert Oppenheimer meant, in 1946, when he said that "the atomic bomb was the turn of the screw. It has made the prospect of future war unendurable. It has led us up those last few steps to the mountain pass; and beyond there is a different country." That different country is our country now, our world.

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On July 16, 1945, at 5:29:45 A.M., the Trinity test was the capstone of a twenty-eight-month effort to develop atomic explosives.

The atomic bombs exploded over Hiroshima and Nagasaki didn't *win* the Pacific war, but without question they *ended* the war. Those first atomic bombs, made by hand here on this mesa, fell into a stunned prenuclear world. Afterward, when the Soviets exploded a copy of Fat Man built from plans supplied by Klaus Fuchs and then went on to develop a comprehensive arsenal of their own, matching ours; when the hydrogen bomb increased the already devastating destructiveness of nuclear weapons by several orders of magnitude; when the British, the French, the Chinese, the Israelis and other nations acquired nuclear capabilities, the strange new nuclear world matured.

Bohr proposed once that the goal of science is not universal truth. Rather, Bohr thought, the modest but relentless goal of science is "the gradual removal of prejudices." The discovery that the earth revolves around the sun has gradually removed the prejudice that the earth is the center of the universe. The discovery of microbes is gradually removing the prejudice that disease is a punishment from God. The discovery of evolution is gradually removing the prejudice that *Homo sapiens* is a separate and special creation.

The closing days of the Second World War marked a similar turning point in human history, the point of entry into a new era when humankind for the first time acquired the means of its own destruction. Nuclear weapons, the ultimate containers of manmade death, made the consequences of sovereign violence starkly obvious for the first time in human history. Since there was no sure defense against such weapons, they also made the consequences certain.

Every great and deep difficulty bears within itself its own solution. Nuclear weapons, encapsulating potential human violence at its most extreme, paradoxically demonstrate the *reductio ad absurdum* of manmade death. These fifty years have been a dangerous but probably inevitable learning experience.

Robert Oppenheimer examined many of these issues forty-eight years ago, in a speech to the Association of Los Alamos Scientists here on the Hill on November 2, 1945. It was harder then to hear what Oppy had to say than it is now, in the aftermath of the long Cold War, when the nuclear arsenals are standing down. Let me repeat some of his words:

"There are things which we hold very dear [Oppy said that night forty-eight years ago], and I think rightly hold very dear; I would say that the word democracy perhaps stood for some of them as well as any other word. There are many parts of the world in which there is no democracy. There are other things which we hold dear, and which we rightly should. And when I speak of a new spirit in international affairs I mean that even in these deepest of things which we cherish, and for which Americans have been willing to die—and certainly most of us would be willing to die—even in these deepest things, we realize that there is something more profound than that; namely, the common bond with other men everywhere."

With the discovery of how to release nuclear energy, and the long, progressive demonstration of its inevitable consequences, science became the first institution powerful enough to challenge the system of nation states that had aggrandized itself with technology to the point of pathological destructiveness. Oppy also spoke of that phenomenon, and explained how it happened that an unarmed, peaceful, international institution such as science had quietly but decisively become a dominant political influence in the world:

"But when you come right down to it [Oppy said] the reason that we did this job is because it was an organic necessity. If you are a scientist you cannot stop such a thing. If you are a scientist you believe that it is good to find out how the world works; that it is good to find out what the realities are; that it is good to turn over to mankind at large the greatest possible power to control the world and to deal with it according to its lights and its values. . . . It is not possible to be a scientist unless you believe that the knowledge of the world, and the power which this gives, is a thing which is of intrinsic value to humanity, and that you are using it, to help in the spread of knowledge, and are willing to take the consequences."

So now, fifty years later, fifty years after this city on a hill opened its doors, when we know what the consequences are, I believe the world owes you, and those of your colleagues who are gone now and no longer among us, an immense debt of gratitude. With courage, with vision, and with intelligence, braving the most cruel part of reality, you started us down the road toward removing a terrible scourge from the earth. Knowledge is itself the basis of civilization, and you helped civilize us.

Richard Rhodes
Extracted from remarks made at the fiftieth anniversary of the founding of the Laboratory at Los Alamos, June 10, 1993

NATIONAL SECURITY NEEDS

"The United States must and will retain strategic nuclear forces sufficient to deter any future hostile foreign leadership with access to strategic nuclear forces from acting against our vital interests and to convince it that seeking a nuclear advantage would be futile.... I consider the maintenance of a safe and reliable nuclear stockpile to be a supreme national interest of the United States.... We can meet the challenge of maintaining our nuclear weapons deterrent under a Comprehensive Test Ban Treaty through a Science-Based Stockpile Stewardship program without nuclear testing."

President Bill Clinton, August 11, 1995

The Trinity explosion represented the culmination of an astonishing confluence of scientific, technological, and industrial capabilities. Much has been said and written about the scientific aspects of the Manhattan Project, but understanding the technological and industrial aspects is important as well. When World War II started, the scientific understanding that nuclear processes could lead to explosives was already widespread at many sites around the world. The success of the Manhattan Project was due in large part to the industrial-scale development of materials processes for the separation of uranium-235 and the production of plutonium and to the resolution of subsequent technological issues surrounding the rapid assembly of the plutonium weapon. Today's thermonuclear weapons are technically complex devices that still rely on a foundation of highly specialized manufacturing capabilities for their maintenance and support.

More than fifty years after Trinity, the nation is again asking what must be done to ensure the safety and reliability of its nuclear weapons. Since 1992 the weapon systems in the stockpile have continued to age—with no nuclear tests being conducted. Every year the directors of the weapon laboratories are required to certify that the weapons continue to be safe and reliable and that testing is not required. We have new techniques and are developing others to measure, anticipate, and remedy the effects of aging on the stockpile in order to fulfill this requirement. The task is difficult and success cannot be assured.

Los Alamos brings to this task scientific and technological capabilities developed over the last fifty years that are unmatched in the world, capabilities in nuclear weapon technology, complex experimentation, and analysis. Forged in the Manhattan Project, the ability to bring interdisciplinary teams together to solve complex problems for the nation remains the Laboratory's most important attribute. We are applying these capabilities to other aspects of our central mission as well, to issues of nuclear materials management and disposition, to nonproliferation and counterproliferation activities, to the cleanup of the Cold War legacy, and to problems in conventional defense.

"This week in this place, we take a giant step forward. By overwhelming global consensus, we make the solemn commitment to end all nuclear testing for all time. The CTBT is the shared work of hard negotiation. Some have complained that it does not mandate total nuclear disarmament by a date certain. I would say to them, do not forsake the benefits of this achievement by ignoring the tremendous progress we have already made toward that goal."

President Bill Clinton
The Fifty-First General Assembly of the United Nations
September 24, 1996

The Path to Science-Based Stockpile Stewardship and Management

In 1992 the United States conducted its last nuclear explosive test and halted production of new nuclear weapons. In September 1996 President Clinton signed the zero-yield Comprehensive Test Ban Treaty and codified science-based stockpile stewardship as a condition of U.S. entry into the treaty.

Historically, our confidence in the safety, reliability, and performance of the weapons in the U.S. stockpile was maintained through rigorous development and testing programs for new nuclear weapons—a combination that ensured both the quality of the weapons in the stockpile and the preservation of the unique skills of U.S. weapon experts. Moreover, potential problems associated with aging materials and components were largely circumvented by the development and production of new weapons designed to meet the military's modern delivery systems and evolving requirements.

Today, confronted with an aging stockpile, we must maintain a high level of confidence without nuclear testing and without the benefit of new design and production. Over the past four years, science-based stockpile stewardship and management have evolved to address the associated scientific and technical challenges, and scientists and engineers are relying on a set of innovative experiments, tools, and facilities to obtain the necessary data relevant to the safety, reliability, and performance of nuclear weapons.

The Role of Los Alamos

Los Alamos bears a heavy burden in maintaining the nation's nuclear forces. When anticipated arms-control initiatives take effect early in the next decade, Los Alamos will be responsible for over 80 percent of the enduring stockpile—five of the seven types of weapons expected to remain in the inventory are Los Alamos designs. The annual certification of these weapons depends on our ability to evaluate the condition of materials and components, to predict the probable consequences of any observed changes, and to implement effective response measures. The promise of our stewardship role is now being fulfilled through our steady focus on traditional and enhanced surveillance activities, remanufacture and refurbishment plans, predictive computer modeling, rigorous experimentation, and improved scientific understanding.

Aggressive, tightly coupled experimental and computational programs are essential for performing credible stockpile assessments and maintaining nuclear design competence—the hallmark of effective stewardship. Experiments create the reality against which we benchmark our computer calculations and theoretical advances, and they integrate many of the practical aspects of weapon design and performance. However, since no single experiment can simulate all aspects of a nuclear explosion, we must make use of an appropriate suite of complementary techniques and specialized facilities.

Extending Our Capabilities

In the post–Cold War era, the number of nuclear weapons in the enduring stockpile is decreasing, and our nuclear weapon manufacturing capacity has been greatly reduced. However, we have expended great effort to ensure that essential capabilities are retained.

Many specialized skills are required for evaluating and responding to weapon issues, whether the stockpile contains 3000 or 300 weapons. Stewardship involves highly diverse tasks, such as addressing stockpile issues and certifying their resolution, supporting assessments of proliferation and military threats, providing adequate capability and capacity for refurbishment and replacement, ensuring safe dismantlement of weapons, and ensuring credible capability for the reconstitution of the stockpile if necessary.

Most of the scientists and engineers with practical nuclear weapon design and testing experience will likely retire within the next ten to twenty years; their knowledge must be preserved and passed on to the next generation of stockpile stewards. The Laboratory's unique knowledge base must also be enhanced and extended. Research into new areas of physics, materials science, engineering, computations, and other critical fields is essential if we are to attract talented professionals who can keep us at the forefront of weapon science and technology and protect the nation from adverse technological surprises or accidents that might result from the loss of crucial knowledge.

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Technicians disassemble a warhead. The United States is reducing its stockpile dramatically in response to treaty agreements.

Annual Certification

The culmination of science-based stockpile stewardship is the formal annual certification of the nuclear weapon stockpile. The certification process requires that the Secretaries of Defense and Energy formally notify the President that the U.S. nuclear stockpile is safe and reliable and that nuclear testing is not necessary for certification. The first annual certification was completed on February 7, 1997. The directors of the three nuclear weapon laboratories in a letter to the Secretaries of Energy and Defense state their personal and direct assessment of the safety and reliability of the stockpile. The Chairman of the Joint Chiefs of Staff, the Commander in Chief of the U.S. Strategic Command, and the Nuclear Weapons Council must all reach concurrence on the assessment before it is forwarded to the President.

The View from the Department of Energy

This is my fifth year with the Department of Energy, and I have been working on stockpile stewardship almost since the first day I walked into the Forrestal Building. It seems to be a good time to reflect on the stewardship program and share some thoughts with the people who are on the front lines of making stewardship happen.

We are in the nuclear weapon business. Nuclear weapons ended World War II, and they were essential in keeping the Cold War cold. One can look back and question whether we needed *all* those nuclear weapons, but none were ever fired; the Soviet Union no longer exists and World War III never happened. In terms of lives lost to military conflict, we are living in a period of historic peace.

But preventing World War III no longer requires the huge arsenal of nuclear weapons of the Cold War. As best we can tell, the ones we have now will do the job. And one way to keep the lid on nuclear arsenals is to inhibit the deployment of new types of nuclear weapons; and the most straightforward way to do that is to eliminate nuclear tests—hence the Comprehensive Test Ban Treaty.

So our job becomes keeping World War III from happening by putting a system into place that will maintain our nuclear weapon stockpile indefinitely, without nuclear testing. This is an awe-inspiring, eye-popping task, and what makes it all the more awesome is that we have so short a time to get it done.

With aging weapons and the retirement of designers with nuclear device test experience, to say nothing of the decay of tritium, we have about a decade to demonstrate that this extraordinary task can be accomplished. I think it fair to say that not since the Apollo Program has the nation been faced with such an audacious, time-urgent technological challenge.

I am confident we can succeed; the stockpile can be maintained indefinitely, without nuclear testing, if the program is supported and organized properly. I believe the program will be supported if we collectively make a coherent case.

The scientific and technical progress to date has been remarkable—extraordinary—ASCI, LANSCE, laser cutting, enhanced surveillance, results from the accelerator production of tritium program, the B61-11 modification. All of this and more demonstrate a scientific and industrial system that is working with considerable vigor. The briefings that I receive are filled with real results, real progress, and are given with a spirit of excitement and confidence.

When President Clinton announced that the United States would seek a “zero-yield” comprehensive test ban, he reiterated the need to maintain nuclear deterrence in the post–Cold War era and stated that the safety and reliability of the nuclear weapon stockpile was a “supreme national interest.” He stated that he would depend upon the directors of the national security labs to advise him on whether that supreme national interest was being met. He did not say it would be easy, or without controversy. Clearly, it is a supreme national scientific and technical challenge, one that is worthy of our very best national effort.

We have made a splendid start, one that I am proud to be associated with. I have been in the national security business now some thirty-five years, and I can think of no other single program that sits at such an amazing conjunction of history, policy, science, technology, and organization. If we do it right, I think we can be the model of how great national programs should be run, and what national labs are all about. What we have accomplished over the past four years is enough to convince me, and I hope all of you as well, that with courage and discipline we can succeed—indeed, we must succeed.

Victor H. Reis
Assistant Secretary for Defense Programs
United States Department of Energy

Stockpile Stewardship and Management

In close collaboration with the DOE weapon laboratories and production plants, DOE and Department of Defense have developed a detailed plan for stockpile stewardship and management. Described in the classified “Green Book,” the plan defines specific roles and responsibilities and identifies unique facilities and capabilities. With this detailed, up-to-date roadmap, we are implementing the plan according to prioritized assignments but without duplication of effort, overlooked responsibilities, or gaps in essential capabilities.

Effective stewardship and management rely on three interconnected areas of activity, which provide the technical basis for continued certification and reliability assurance:

- surveillance—standard and enhanced techniques to diagnose and predict age-related phenomena in stockpile weapons;
- assessment—experimental and computational methods that advance our understanding of how aging and new manufacturing processes affect weapon safety and performance; and
- response—development of appropriate measures, based on expert assessments, that may include modifications to or remanufacture of warheads and components and/or changes in operational procedures.

Carrying out our national security missions without nuclear testing requires that we enhance our existing tools and develop new approaches for gathering data and sustaining core capabilities. To meet our manufacturing missions, we must also modernize our facilities and production capabilities. We have identified five focus areas that are essential to our ability to fulfill our responsibilities now and that must be nurtured if we are to continue to do so in the future: high-performance computing, hydrodynamic experiments, materials science, high-energy-density physics, and nuclear materials technologies and the facilities that support manufacturing and research and development activities.

High-Performance Computing

Computer simulations have traditionally played a central role in the design and analysis of nuclear weapons. From the Manhattan Project era until the early 1980s, the U.S. nuclear weapon program drove the rapid progress of the high-end computer industry. By the mid-1980s, however, the Cray vector supercomputers were adequate for designing new nuclear weapons, and nuclear testing provided the ultimate confidence in the safety, reliability, and performance of those designs.

As a result, the push toward larger, faster computers began to wane, and progress in high-end computing slowed considerably.

Once again, however, the nuclear weapon program is providing the impetus for the accelerated enhancement of supercomputing capabilities. The reason is simple: the nuclear stockpile is aging. Generically, aging produces chips, gaps, cracks, and corrosion in and among the various components of a weapon. These effects introduce small defects that alter the symmetries the physicists and engineers invoked when designing the weapon. With the end of nuclear testing, numerical simulations are now our only method of gaining a comprehensive knowledge of the many complex processes that take place in a thermonuclear weapon. The continued certification of the safety and reliability of the nation's nuclear stockpile rests heavily on our ability to perform reliable, integrated computer simulations.

Transport Modeling

Transport processes relate to the passage of radiation through matter, neutrons through fissile atoms, and the momentum and energy carried through a fluid by molecular fluctuations or turbulence. Transport processes are often extremely complicated to describe with precision, principally because they involve the macroscopic manifestations of chaotic behavior at very fine scales. Models that credibly represent the important collective features are absolutely essential to the accomplishment of our responsibilities for science-based stockpile stewardship. These models lie at the heart of the Laboratory's core competency for state-of-the-art computation of complex systems, especially for the new codes being developed for the Accelerated Strategic Computing Initiative (ASCI).

The development of transport models has taken great strides in recent years. Monte Carlo (statistical) techniques for both radiation and neutron transport complement deterministic solution procedures and now give vastly improved accuracy for problems ranging from nuclear weapon issues to astrophysics. Transport models now describe the movement of turbulence through space on size scales from the finest, where energy transforms to heat, to the largest, where turbulence is a major contributor to the transport.

Complementing the analytical and computational work on transport processes are the experimental activities that produce data essential for validation of the models. We share many of these results (theoretical, computational, and experimental) with investigators at other laboratories and universities throughout the world, and we receive in return valuable responses that ensure our continuing presence at the forefront of transport analysis.

Accelerated Strategic Computing Initiative

To effectively identify, evaluate, predict, and mitigate the myriad effects of aging without nuclear testing, we require computational speeds and memory capacities well beyond what is currently available. We estimate that assessing the effects of symmetry-breaking defects on the safety and performance of the aging stockpile will require an increase in computational power by a factor of 100,000, or five orders of magnitude. DOE, the three weapon laboratories, and the high-end computer industry have committed to a partnership, ASCI, to achieve this goal in less than a decade. ASCI also supports three new code projects to produce a full-physics, full-system code optimized to run efficiently on the new machines. ASCI will enable us to perform three-dimensional modeling and simulation that will integrate the essential elements of science-based stockpile stewardship.

For approximately ten years the massively parallel supercomputer thrived in the United States. These computers were the most sophisticated, most advanced machines ever created. In the early 1990s, industry grew weary of the constant evolution of hardware without a complementary evolution of software. With each new machine came the development of new computer codes that were incompatible with other codes. Thinking Machines Corporation and other supercomputer companies faded away, leaving only the machines themselves.

Although massively parallel supercomputers were becoming a thing of the past, the demand remained for systems that perform trillions of operations per second (teraflops) and have the storage capacities of an exabyte (10^{18} bytes). The nuclear weapon program began to shift from fifty years of nuclear testing to a future of computer simulations and nonnuclear tests. Science-based stockpile stewardship requires substantial increases in computing power. The goal of ASCI is to advance computational modeling and simulation capabilities by five orders of magnitude over what exists today, through multiple partnerships with the high-performance computing industry. These partnerships are based on accelerating the industry partner's corporate business plan so that ASCI can use high-end hardware systems from commercial sources.

To ensure that this program succeeds, the ASCI team (Los Alamos, Lawrence Livermore, and Sandia National Laboratories) has developed multiple strategies. First, the team's focused applications-development effort will develop three-dimensional, full-physics, full-system applications. Second, the team's computing-platform strategy focuses on the highest levels of computing capability. Third, the team will develop a computational infrastructure to support the development and use of the new three-dimensional applications. These three key strategies create a balance between hardware, software, and infrastructure. With this strategy in mind, the ASCI team plans to complete three principal goals by the year 2010:

- Develop high-performance, full-system, full-physics predictive codes to support weapon design, production analysis, accident analysis, and certification.
- Stimulate the U.S. computer-manufacturing industry to create a more powerful high-end-supercomputing capability required by these applications.
- Create a computational infrastructure and operating environment that makes these capabilities accessible and usable.

Archiving and Reanalysis of Nuclear Test Data

One of our most important responsibilities is to ensure that critical information from fifty years of nuclear weapon testing and development is properly preserved. These data will provide the ground truth for nuclear weapon

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First installation of computers for the Accelerated Strategic Computing Initiative (ASCI) at Los Alamos, February 1997.

modeling and analysis, and their reanalysis provides a starting point for questions that arise about the aging stockpile. We are systematically examining, evaluating, and documenting Laboratory records, particularly those related to nuclear weapon engineering, nuclear weapon test data, and hydrodynamic test data.

Hydrodynamic Testing

Hydrodynamic tests are high-explosives-driven experiments for studying the primary implosions of nuclear weapons. High-resolution, flash-x-ray radiography is one of the principal diagnostic tools for these tests. Flash radiography does not perturb the experiment in any way, and thus it yields an accurate measure of whether the explosive performance matches theoretical, computational, and engineering predictions. The images provide data related to the density of compressed materials and the location and nature of material interfaces. Such experiments constitute our most important aboveground, nonnuclear testing capability because they let us examine the position, velocity, and condition of material surfaces, as well as the propagation and pattern of wavelike disturbances.

The DARHT Facility

The Los Alamos dual-axis radiographic hydrotest (DARHT) facility is under construction. When completed, it will be one of the principal tools for evaluating and ensuring the safety and reliability of the enduring nuclear stockpile. The x-ray bursts from DARHT will be ten times more effective than those available at our present flash radiographic facility. DARHT will house advanced optical and electronic diagnostics necessary to conduct full-size hydrodynamic tests of nonnuclear mockups of nuclear weapon primaries. Moreover, DARHT will provide the capabilities for experiments investigating shock physics, high-velocity impacts, materials science, high-explosives science, and industrial applications.

Subcritical Experiments at the Nevada Test Site

Subcritical experiments, planned for the Nevada Test Site, involve high explosives and nuclear materials such as plutonium, but the experiments are designed not to produce self-sustaining nuclear reactions. This category of experiments is thus termed *subcritical*, and these activities are consistent with the zero yield required by the Comprehensive Test Ban Treaty. Subcritical experiments are designed to complement dynamic experiments conducted at other facilities such as DARHT and to help address the concerns that arise as we evaluate weapon performance. On July 2, 1997, Los Alamos successfully conducted Rebound, the first in a series of subcritical experiments at the Nevada Test Site using high explosives and plutonium. The purpose of Rebound was to gather basic materials data on plutonium at very high pressures. Rebound was the first in a series of subcritical experiments to be conducted in support of science-based stockpile stewardship.

Materials Science

If we expect weapons to remain in the stockpile indefinitely, it is imperative that we understand how they age. A central element of our stockpile stewardship and management program is developing the necessary understanding of materials aging that will enable us to make informed decisions about component changes. We are upgrading the capabilities of the Los Alamos Neutron Science Center (LANSCE) to probe materials aging at the atomic and molecular levels, and we are developing new methods to radiograph weapons and components with protons to reveal the conditions of internal parts that cannot be assessed with x-rays or by any other method. In addition, we will use these techniques to study dynamic phenomena, including the processes deep inside detonating high explosives. A gas gun, now operational at our plutonium facility, is used to examine the shock-response properties of plutonium, complementing the subcritical experiments. We are also concerned with the aging characteristics of the plasticizers used to bond high explosives together, particularly the effects of radiation-induced chemical reactions in these materials. The entire suite of materials characterization and synthesis capabilities at the Laboratory are available to these investigations.

LANSCE and Proton Radiography

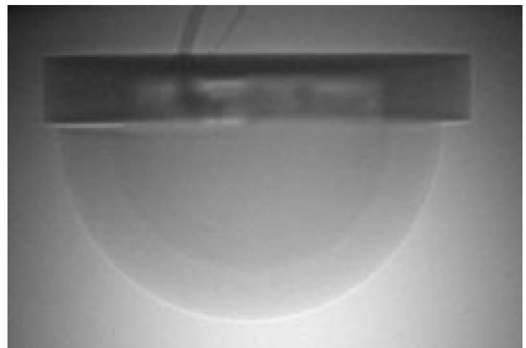
LANSCE is a powerful accelerator and spallation neutron facility that includes the Manuel Lujan Jr. Neutron Scattering Center, the Weapons Neutron Research facility, the world's most powerful proton linear accelerator, and a proton storage ring. Researchers use LANSCE to address a range of issues critical to long-term weapon stewardship. At the Lujan Center, neutron-scattering techniques including neutron diffractometry, small-angle scattering, reflectometry, and inelastic scattering are used to develop new methods for weapon surveillance, to aid in the design of processes for remanufacture, and to study the effect of aging on weapon components. Lujan Center research, for example, provides information that will guide modeling of the hydrodynamic performance of aged plutonium and the sensitivity of aged and damaged high explosives.

Scientists at the Weapons Neutron Research facility provide nuclear data to refine the interpretation of results of past weapon tests, strengthening the linkage of new computational tools that are developed as part of ASCI with the weapon test data archive. Another important initiative at the facility is the development of neutron resonance spectroscopy techniques to measure temperatures and velocities in the interior of dynamic systems on a time scale of microseconds, a new capability for weapon-relevant, shock-wave physics studies.

In collaboration with researchers at Lawrence Livermore National Laboratory, scientists at LANSCE successfully demonstrated proton radiography, a new approach to multiple-snapshot, flash radiography using beams of high-energy protons. Scientists have already applied proton radiography at LANSCE to an important stockpile certification issue in high-explosives performance, and a LANSCE and Livermore team is developing the technology at higher proton energies as a possible new method for dynamic radiography.

Aging of Polymeric Materials

Degradation of polymers and high explosives will limit the lifetime of many stockpile



Proton radiographs of small hemispherical high explosives at two different times. The radiographs, obtained with the 800-million-electron-volt proton beam at the Los Alamos Neutron Science Center (LANSCE), clearly reveal the progress of the detonation wave.

components. There are approximately 60 types of polymeric materials and 200 polymeric components in the stockpile. We are working to identify and characterize aging mechanisms in these polymeric materials and to predict material properties over an extended lifetime. A variety of analytical techniques provide insight into changing chemical and mechanical properties. We derive models and then test them by comparing them with stockpile parts from the surveillance program and accelerated aging studies. The models then allow lifetime predictions by extrapolating known material properties. We have established a network with the production plants and the other weapon laboratories that enables collaboration, information exchange, and peer review of these activities.

High-Energy-Density Physics

Thermonuclear explosions involve temperatures, densities, and pressures reached only in the cores of the sun and other stars—hence the term *high-energy-density physics*. Understanding the behavior of materials under these conditions is crucial to the science of nuclear weapon design and performance. We gained most of our knowledge of the behavior of materials under these conditions through theoretical calculations verified by nuclear tests.

Without underground nuclear tests, we must develop laboratory experiments that approach the conditions of nuclear explosions. The experiments will provide more accurate information about the physical properties of matter in the high-energy-density regime, as well as the means to develop and maintain the skills required to understand nuclear weapons. Two different approaches—pulsed power and lasers—create the extreme conditions needed for experiments in weapon physics. Each approach allows us to achieve unique aspects of the high-energy-density regime. High-energy lasers provide the highest temperatures and pressures, but only in relatively small experimental volumes and only for a few billionths of a second. Pulsed power can focus much greater energy on a larger experimental target for a much longer time, although at somewhat lower temperature and pressure.

Pegasus II Pulsed-Power Facility

Pegasus II delivers electrical energy from a capacitor bank to a cylindrical aluminum shell, called a liner, in about 10 microseconds, producing an electrical current as high as 12 million amperes in the 3-gram liner. The magnetic field produced by this enormous current implodes the liner at velocities as high as 10 kilometers per second. For some experiments target packages are placed inside the hollow liner, and the resulting impact is studied. This work allows for systematic investigation of various weapon physics issues.

Atlas Pulsed-Power Facility

Atlas is a pulsed-power facility designed for high-energy-density experiments supporting programs in weapon physics and basic research. Planning for Atlas began in 1993; the design work started in 1996; and the facility is scheduled to be operational in the fall of 1999. Atlas will have a total storage capacity almost ten times that of Pegasus II. The facility will support large-scale hydrodynamic experiments at pressures and temperatures high enough to ionize materials, and it will enable us to model and study implosion dynamics and material properties on a realistic, readily diagnosable scale in order to evaluate the effects of aging and corrosion in stockpiled weapon components.

Inertial Confinement Fusion and the National Ignition Facility

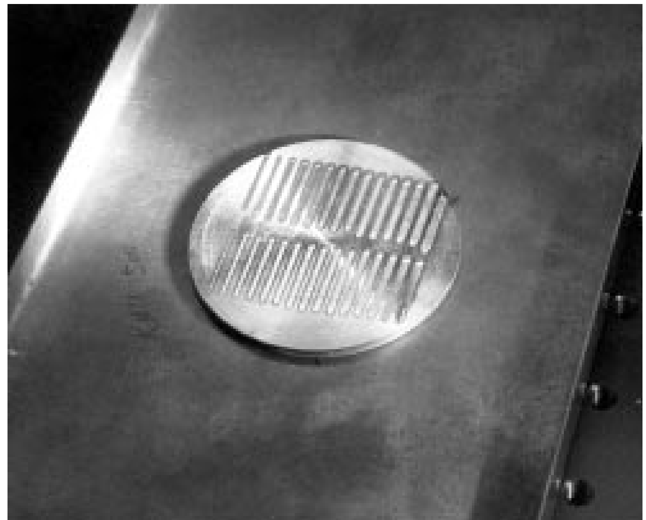
Los Alamos is participating in the national inertial confinement fusion program and development of the National Ignition Facility at Lawrence Livermore National Laboratory. We are conducting experimental studies at the largest laser facilities around the world to verify our understanding of laser-driven inertial confinement fusion and, in some cases, to point the way to significant advances in our theories of how laser beams interact with matter. Los Alamos is chiefly responsible for the development of several important computational approaches to the design of laser targets for the National Ignition Facility: a three-dimensional particle-in-cell code, integrated target modeling, and direct numerical simulation of capsule stability.

Target Fabrication for Inertial Confinement Fusion Experiments

Los Alamos carries the primary responsibility for target fabrication for inertial confinement fusion experiments. Fabrication requires the interplay of capabilities in coating technologies, foam fabrication, precision machining, materials characterization, and microassembly, including the incorporation of difficult materials such as beryllium and tritium. Target elements typically undergo numerous coating, machining, and characterization steps on sacrificial forms before the forms are removed chemically, and then the freestanding parts (the largest dimension is often less than 1 millimeter) are incorporated into a complete target with all components in precise, three-dimensional spatial alignment.

Nuclear Materials Technology

Los Alamos has played a leading role in addressing a variety of technical issues relevant to fissile materials, especially plutonium.



Plutonium button etched by a laser beam as part of a demonstration of advanced materials technology.

As the nation's only fully functioning plutonium facility, Los Alamos offers a complete range of plutonium-processing, handling, fabrication, and research and development capabilities.

The termination of plutonium operations at many other DOE sites resulted in Los Alamos becoming DOE's designated location for research, development, and manufacturing operations for plutonium and other actinide materials. The nation's ability to ensure the reliability of the enduring stockpile, manufacture war-reserve plutonium pits, develop new technologies to prevent the proliferation of plutonium, develop and demonstrate technologies to stabilize and store residues, develop material disposition options, and maintain nuclear heat source capabilities depends largely on the continued safe and compliant operations of the Laboratory in nuclear materials technology.

From the 1960s through the 1980s, nuclear materials technologies were *bucket-and-shovel* chemistry and *heat-and-beat* metallurgy that enabled the massive buildup of nuclear weapons during the Cold War. The Laboratory's mission in nuclear materials has dramatically changed, and the technology base must evolve into a more scientific understanding of fundamental materials properties and principles. In addition, we must develop a stronger engineering basis for handling, processing, manufacturing, and using plutonium, uranium, and other light actinides, because many of the processes once used for these operations are no longer acceptable from a health, safety, or environment standpoint.

Advances in nuclear materials science will enable the current and upcoming requirements of science-based stockpile stewardship and management, legacy cleanup, and weapon disposition. In addition, as the Laboratory undertakes the manufacturing of plutonium pits, new technologies are needed to reduce the environmental and safety hazards associated with these operations. In turn, these materials capabilities will apply to energy production, space exploration, and other civilian applications.

Miniflyer Plates for Dynamic Experiments

We are developing methods for the laser-launching of miniature, flat flyer plates for generating dynamic data on samples of returned pit materials, especially plutonium. The miniflyer plates, which use pit samples as targets, provide an experimental method for generating and quantifying the dynamic response of plutonium to stress-strain states that typically occur during the implosion of the primary. In addition, using miniflyer plates offers the advantages of reduced cost, ease and versatility, and safety over conventional experimental methods.

Calorimetry

Calorimeters measure heat generated by radioactive materials as they decay and allow the mass of the material to be determined accurately. When the Mound facility in Ohio closed, the calorimetry program was moved to Los Alamos, where the calorimetry assay laboratory opened last October. We will continue the work of the Mound program, which includes establishing heat calibration standards for use throughout the complex, training specialists in calorimeter assay techniques, and providing support to other DOE facilities using the devices. Earlier this year the Laboratory built a calorimeter for use at the plutonium facility and will supply another unit for the Advanced Recovery and Integrated Extraction System pilot project.

Nuclear Materials Facility Upgrades

Los Alamos has the responsibility for providing the full range of plutonium technologies, manufacturing, and surveillance activities to DOE—a service workload that is increasing with time. The network of unique but venerable technical facilities important to this work has needed modernization improvements for some time.

We are installing an upgraded security and access control system and alarms. We will also replace or establish new perimeter intrusion detection and assessment systems at key nuclear facilities and install a new Laboratory-wide fire alarm system.

Renovations at our plutonium facility will provide extensive upgrades to safety systems and associated facilities and will also address the modifications required for limited-scale pit manufacturing and its integration with research and development. Though it is the nation’s newest weapon plutonium facility, it is more than twenty years old and suffering some predictable problems that necessitate its refurbishment.

Renovation of the nuclear materials storage facility, which is adjacent to the plutonium facility, begins this year. The facility must be in operation by 2002 because the existing storage vault will be at capacity by that time and because pit-surveillance and manufacturing operations will create growing storage needs.

Dominating the western end of our actinide corridor is the forty-five-year-old Chemistry and Metallurgy Research building. This large building houses analytical chemistry laboratories crucial to the support of nuclear materials operations at the plutonium facility, including pit surveillance. Analytical chemistry tasks include, for example, preparing and certifying plutonium standards, stabilizing nuclear materials, and characterizing radioactive waste constituents. Renovation of the building is a major project scheduled for completion in 2002.

Stockpile Support Operations

Los Alamos directly supports stockpile maintenance through the engineering, testing, and manufacturing of weapon subsystems. Extending the life of nuclear weapon systems without new designs will require engineering upgrades because many processes for their manufacture are no longer available. Many subsystems in nuclear weapons have limited lives and must be replaced periodically. Furthermore, the surveillance of stockpile weapons—a key component of science-based stockpile stewardship and management—destroys some components, particularly pits, which must be replaced. In addition, devices for flight and other nonnuclear tests must be produced for the military and other facilities in the complex.

B61-11 Development

In 1995 Los Alamos was tasked with the design, testing, and certification of a modification of the B61 bomb, called model 11. The modified weapon, a B61 model 7 retrofitted to a new exterior package, would replace the B53 bomb in the stockpile. The B53 is the oldest design in the stockpile and lacks many modern safety features. The modification allows DoD to modernize its inventory while continuing to meet the military requirements for holding deeply buried and hardened targets at risk. The work, initially scheduled for completion in August 1997, was accelerated so that delivery to the stockpile could be made in December 1996. As a result of the compressed schedule, many tasks were conducted in parallel. We used previous experimental data as much as possible and conducted a number of engineering tests to determine the environment the weapon had to withstand. We then conducted a series of component survivability tests for these levels. The tests demonstrated that a B61-7 could be retrofitted into a B61-11 casing. In October 1996 a full-scale hydrodynamic test confirmed that package changes did not adversely affect B61-7 performance. In January 1997 the B61-11 was accepted as a limited stockpile item; we expect full certification in 1998.

Acorn Development

A JASON panel recently recommended that the laboratories pursue boost-system development as a means of enhancing the design margin in the aging nuclear stockpile. Los Alamos and Sandia National Laboratories are jointly developing the Acorn boost system to replace this limited-life component in stockpile weapons. Acorn technology has been researched for about twenty years and its applicability was demonstrated in the 1980s on an unfielded weapon system. Acorn advantages include cost-effectiveness, no required nuclear testing, and no required disassembly of the nuclear package. We have progressed far this year into developing Acorn manufacturing facilities and capabilities. Stockpile deployment of Acorn will be on the W76 warhead next year, followed by modification for the B61 bomb and other weapons.

Tritium Production

Tritium, a gas with a 12.3-year radioactive half-life, is used in all U.S. nuclear weapons to increase the explosive force of the warhead. Tritium's natural radioactive-decay process requires regular maintenance, during which decayed tritium is removed and replaced. However, since the United States currently has no source for tritium production, DOE is recycling tritium from dismantled weapons to meet current stockpile requirements. A new production source may be needed as early as 2007. To ensure an adequate supply of tritium for the future and at least one viable alternative, DOE is pursuing a dual-track strategy, investigating two technology paths simultaneously—reactor- and accelerator-based options. The reactor-based option is fraught with policy obstacles—using civilian reactors for weapon material production; the accelerator-based option involves some technical risks.

Los Alamos is the technical leader for the accelerator production of tritium (APT) project. The APT project team will use a proton accelerator to produce a very high flux of neutrons by spallation, which will in turn produce tritium through interactions with helium-3. APT provides significant environmental and safety advantages when compared with reactor production, because APT uses no fissile material and has the flexibility to meet changing tritium requirements should stockpile needs change in the future. DOE will choose between the options in 1998.

Los Alamos is leading the project. Burns and Roe Enterprises, as the prime contractor, with its partner General Atomics, will work with Los Alamos, Westinghouse Savannah River Site, and other laboratories to complete the engineering, development, final design, and construction.

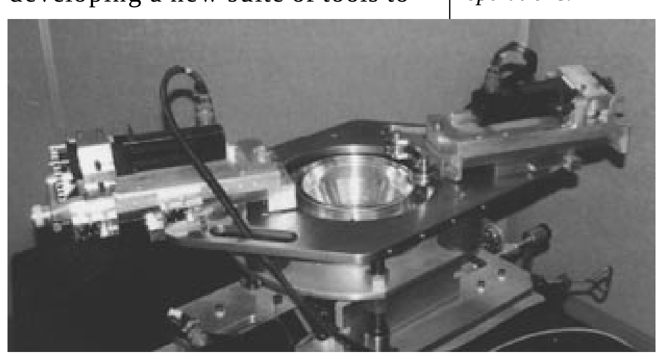
A low-energy, full-current, demonstration accelerator under construction at Los Alamos will provide the design confirmation, operational experience, and reliability assessment of components. The proton injector developed for this demonstration has already met the beam requirements for APT. Superconducting cavities are being built and tested at Los Alamos for a high-efficiency proton accelerator. In addition, technology demonstrations are underway, including materials irradiation and corrosion studies at LANSCE, providing materials and engineering data critical for the final design of the plant.

During the final stages of design, a transition will occur as construction begins at the Savannah River Site in 1999 if DOE chooses to proceed with the accelerator option. Los Alamos will retain design authority for the accelerator, target and blanket, and tritium extraction facilities and will provide technical oversight of APT throughout the life of the project.

Pit Surveillance and Manufacturing

Our core surveillance activities monitor nuclear weapons and weapon components with respect to function, condition, geometry and fit, material properties, and chemical composition. We are also developing a new suite of tools to

Device for cutting open plutonium pits for surveillance operations.



measure, analyze, calculate, and predict the effects of aging on weapon materials and components. The data we gather will enhance our computer models and enable us to forecast the need for modified or expanded manufacturing capacity before serious problems affect the stockpile. This enhanced surveillance focuses on four major areas: materials science, advanced materials modeling, diagnostic development, and systems performance testing. As new technologies and methods are prototyped and validated, they will be integrated into the core stockpile surveillance program.

Los Alamos has the responsibility to provide limited-scale manufacture of plutonium pits (up to fifty per year) for the enduring stockpile by the year 2005. This production level provides ample assurance of maintaining the capability for fabricating all the pit types in the stockpile and of replenishing inventory losses due to surveillance activities. The manufacturing assignment and the new process technologies under development are the basis for designing a modular-production capability for deployment elsewhere if greater capacity is needed in the future. The manufacture of the first certifiable war-reserve pit for the Trident II warhead will be completed in 1998.

Nonnuclear Production Activities

In response to the reconfiguring and downsizing of the nuclear weapon complex, we have applied the historic strengths of our research and development to producing small quantities of war-reserve components for the existing stockpile. Manufacture and certification of components will be different from previous processes in the complex, but the exacting quality standards found in earlier components will be the same.

The Evolution of Detonator Manufacturing at Los Alamos

Los Alamos designs all the primary detonators that are used in Laboratory-designed weapon systems. During the height of the Cold War, this was a continuous task, as the United States frequently designed and fielded new weapon systems to meet the strategic and tactical requirements of its military. Because of the high reliability requirements for nuclear weapon detonators, the detonator design and development work required substantial amounts of testing to validate concepts. Ten years ago, this design activity was the primary pursuit of the Laboratory. The emphasis on testing and reliability led to extensive engineering and fabrication in order to validate new concepts. Only after developing the fabrication processes substantially, would the Laboratory release the designs to the EG&G Mound facility, where actual production for the nuclear stockpile took place.

It was the Laboratory's history of developing designs through intensive fabrication and process development that made Los Alamos the logical choice for high-power detonator surveillance and manufacturing after the closing of the Mound facility in 1993. Los Alamos had produced many thousands of detonators, providing a knowledge base which, when combined with a modern facility, formed a core capability for continued detonator production. Adding the surveillance and manufacturing requirements created an overall detonator capability that includes the resources and knowledge to design and develop, manufacture, evaluate, and improve detonation systems for the enduring stockpile.

Detonator manufacturing at Los Alamos is different from previous manufacturing processes in the complex, but our process maintains the same exacting quality standards applied to components produced earlier. The difference in our approach to manufacturing lies primarily in three areas: First, manufacturing and research and development activities are integrated in the seamless production of cost-effective, high-quality, certified components. Second, this integration provides the means to maintain critical Laboratory skills and expertise while conserving existing resources. Third, manufacturing activities build on our experiences with industrial partners. The combination of research and development and manufacturing has created a synergy that has benefited both.

Neutron Generators

When DOE closed its neutron-generator production plant, generator manufacturing was transferred to Sandia National Laboratories. With many years of experience in tritium operations and tritium research and development, Los Alamos is collaborating with Sandia on this project. Manufacture of tritiated components for Sandia is well underway. In FY 1996 we shipped fifty-three development units to Sandia. During FY 1997, a total of 275 targets had been produced by October; the August shipment was the first complement of war-reserve-quality units. Modifications to the Weapons Engineering Tritium Facility to accommodate this project are underway and should be completed next year.

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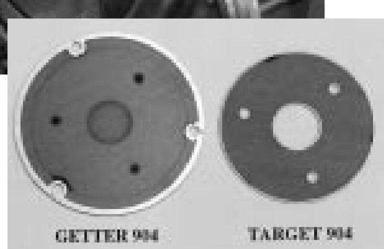

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Glove box for fabricating tritiated targets for neutron generators, and the targets themselves.

Nuclear Materials Management

Because of its expertise in nuclear materials technology supporting the nuclear weapon program, Los Alamos is deeply involved in the management of the materials legacy of the Cold War. The safe disposition of plutonium from weapons and from civilian nuclear power plants, in both the near term and the long term, is critical to reducing the danger from proliferation of nuclear weapons worldwide. The Laboratory plays a key role in the development of technologies for stabilizing weapon plutonium residues from the former Rocky Flats Plant and is involved in numerous other activities related to the management of nuclear materials.

Weapon Component Disassembly and Conversion

A key element of the national disposition program is the conversion of dismantled weapon pits to a stable, unclassified form, assayed and packaged for long-term storage. The material can then be placed under international monitoring and inspection. The Advanced Recovery and Integrated Extraction System (ARIES) is a complete system designed for this purpose. The weapon pit enters the ARIES modular-component glove box, where it is cut in half, and the plutonium product emerges qualified for long-term storage.

Los Alamos has initiated a program to demonstrate a full-scale ARIES prototype with a throughput capacity of 250 to 500 weapon pits per year. The ARIES pilot demonstration project will be operational at the plutonium facility in 1998. The design effort for the full-scale ARIES production facility has also been launched. Much of the ARIES technology is applicable to pit disassembly and conversion in Russia, and ARIES modular components can be adapted to transportable systems for use elsewhere in the United States or in Russia. Los Alamos has initiated discussions with the Russians that ideally will lead to collaborative research and development, to construction of a Russian prototype disassembly and conversion system, and ultimately to a Russian plant producing a steady stream of excess material that is stabilized and packaged into safeguarded and verifiable storage before final disposition.

Disposition of Weapon Plutonium

In a decision announced earlier this year, DOE specified a dual-path approach for fissile materials disposition. Some of the excess weapon material will be made into a reactor fuel of plutonium and uranium mixed oxides (MOX). Although the plutonium would not be consumed during reactor use for producing energy, it would be difficult and very expensive to recover it from spent fuel, saving it from diversion or misuse. Los Alamos has the only U.S. capability for producing this reactor fuel, has demonstrated the fabrication of MOX pellets from weapon material, and is proceeding into a small-scale demonstration phase. Russia is developing MOX technologies as well. This work, with the effort in materials conversion previously described, benefits both countries. The remainder of the excess material would be mixed with radioactive fission products and vitrified—immobilized in a glass or ceramic matrix.

Nuclear Vision Project

The end of the Cold War and other changes in the world situation present us with a compelling opportunity to examine the global nuclear enterprise. The objective of the nuclear vision project is to explore ways to shape, over the next fifty years, the evolution and impact of future nuclear science, materials, energy, and weapon technologies, along with international strategies to minimize nuclear materials, toward a global vision of nuclear benefits with minimal nuclear danger. The basic elements of the project are a series of internal and external exploratory workshops, a set of issues for research and analysis, and an outreach program to link work at the Laboratory with related work elsewhere. Many complex issues will emerge as we explore alternative futures. Understanding these issues may allow policymakers to shape strategies toward optimum outcomes.

Plutonium Stabilization

Los Alamos remains committed to stabilizing its backlog of legacy nuclear materials by the year 2002, a DOE target based on a recommendation from the Defense Nuclear Facilities Safety Board. Los Alamos is the only site to have stabilized and packaged any plutonium or oxide for long-term storage, and we now have 110 filled containers that meet DOE storage criteria. At the end of FY 1997, Los Alamos will be the only site to have met the goal of stabilizing the high-risk items in our storage vault within the three-year DOE time limit. The Laboratory also leads in supporting the DOE stabilizing effort at other sites.

Neutron-Source Recovery

The Laboratory has reestablished a mechanism for retrieving unwanted plutonium-239–beryllium neutron sources from private industry, public educational institutions, and government agencies. Chemical reprocessing of the retrieved sources reduces the radiological risk from unnecessary or inadvertent exposure to gamma and high neutron radiation levels. Overall, we have deactivated about 1000 neutron sources and recovered more than 25 kilograms of plutonium. We have processed 101 sources already this year. With sustained support, the program will continue to remove successfully from harm's way unneeded sources that are sometimes not properly stored, accounted for, or in good physical condition.

NONPROLIFERATION AND COUNTERPROLIFERATION

Over a rapidly changing world loom threats of the proliferation of weapons of mass destruction—nuclear, biological, and chemical (NBC)—and of their potential use by rogue states and terrorists. DOE and Los Alamos have the responsibility for major efforts to understand and counter those threats.

In the last decade, with the end of the Cold War, the breakup of the Soviet Union, the discovery of a clandestine nuclear weapon program in Iraq, and safeguards violations in North Korea, strengthening the nuclear nonproliferation regime has grown in importance to U.S. and international security. At the same time, nuclear arms control agreements to reduce the number of deployed nuclear weapon systems have been implemented.

The Los Alamos role in reducing the danger of nuclear proliferation is of long standing. We have provided detection technologies to monitor clandestine nuclear explosions for over thirty years and have

Damaged americium-beryllium neutron source salvaged by Laboratory personnel.

been deeply involved in the analysis of potential nuclear proliferants. We have provided technical support and analysis to numerous treaty negotiations. As the potential for the proliferation of biological and chemical weapons of mass destruction emerges, we expect our role to include these areas as well.

Nuclear, Biological, and Chemical Weapon Proliferation and Terrorism

More than twenty countries are suspected of some form of NBC weapon proliferation. In addition, subnational, organized crime, and other terrorist groups that could gain access to these materials are of growing concern. Events such as the terrorist use of chemical weapons in the Tokyo subway heighten the gravity of the situation and highlight the vulnerability of U.S. civilians and interests. In addition to the chemical and biological warfare threat is the danger of low-technology nuclear devices and weapons that disperse radioactive material. The threat is real, and the political, societal, economic, and psychological impacts of an attack are potentially devastating. Therefore, U.S. government activities must focus on reducing vulnerabilities to the threat of NBC weapons. This goal can be accomplished by preventing their acquisition, reducing existing capabilities, deterring their use, and developing effective response plans and capabilities to mitigate the impact of their use.

In 1996 Los Alamos helped policymakers to establish a national agenda for reducing the threat of NBC weapon proliferation and terrorism. That agenda broadened DOE's responsibility to include the emerging threat areas, thereby positioning DOE and Los Alamos as major resources for DoD, the intelligence community, and other federal agencies. Having led internationally in nuclear safeguards for more than thirty years, Los Alamos now has a major role in reducing the threat of NBC proliferation and terrorism.

Nonproliferation and Arms Control Policy

Understanding the interactions between policy and technology is essential to developing effective nonproliferation and arms control policies and their associated treaty verification and monitoring systems. Supporting U.S. policy development requires expertise in all aspects of nuclear weapons, cooperative and noncooperative monitoring technologies, and intelligence and knowledge of the U.S. and other-government policy initiatives. Our technical staff has directly supported various treaty negotiations, including the Nonproliferation Treaty, the Comprehensive Test Ban Treaty, and the Strategic Arms Reduction Treaties. We have also negotiated with Russia to ensure the secure transportation of nuclear weapons, protection of nuclear materials, the irreversibility of arms reductions, and verification and disposition options for development of excess fissile materials. Small teams of scientists and policy analysts work in Los Alamos; other team members may be assigned to Washington, Geneva, Vienna, or Moscow. Their efforts benefit policy development and international negotiations by providing sound technical advice on a broad range of issues.

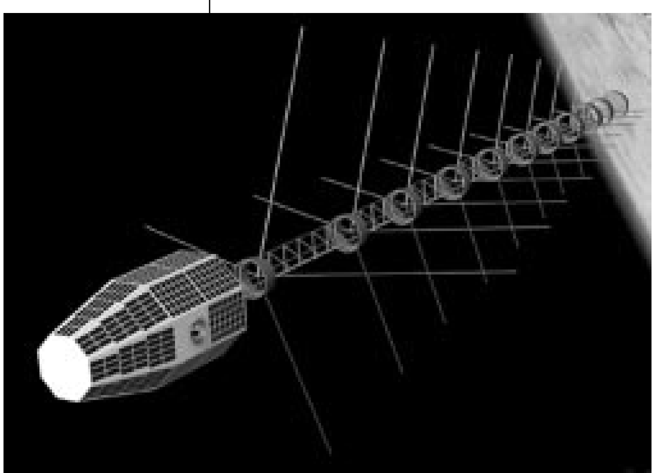
Nuclear Technology Export Control

Los Alamos has developed the software for an automated computer system that will enable the thirty-four-nation Nuclear Suppliers Group to share export license information. The group's central contact point is the Japanese Permanent Mission in Vienna. The Nuclear Suppliers Group Information Sharing System (NISS) helps export-licensing officers in each country to make decisions based not on specific countries but on the end use and end user. The NISS central computers are at Los Alamos. Currently, NISS provides reference information, export license denial notifications, and electronic mail. Probably the most important effect of license denial notification will be to reduce effective *license shopping*, a practice in which those seeking technology send applications to multiple countries in the hope of gaining at least one inadvertent approval.

To date, thirty-two nations have joined the system, with the United States providing identical systems in each country's capital. If needed, countries may provide additional systems, as some have done. All user systems, including those in Washington, D.C., are linked to the computer at Los Alamos, where a special configuration includes a backup machine. The software runs on stand-alone computers connected to the central computer at the Laboratory over commercial telephone lines, with all communications encrypted.

Treaty Verification

Los Alamos continues to provide critical technologies and instruments for both ground- and satellite-based nuclear test monitoring and maintains the expertise required to deduce technical intelligence from the nuclear monitoring data. This year Los Alamos delivered fourteen instruments for inclusion in the Nuclear Detonation Detection System. Seventy-four Los Alamos instruments, verifying compliance with the Limited Test Ban Treaty, are currently operational on twenty-eight satellites. Responding to national Comprehensive Test Ban Treaty requirements for enhanced monitoring capabilities, Los Alamos is demonstrating a new satellite-based, electromagnetic-pulse-detection technology and new regional, seismic-monitoring methodologies for detection of clandestine underground nuclear tests.



The FORTÉ satellite, launched this August, will test concepts for treaty verification and contribute to basic scientific investigations.

Fast On-Orbit Recording of Transient Events

Los Alamos is a leader in the national trend to smaller, inexpensive, and more capable spacecraft and instrumentation. Our orbiting advanced-technology demonstrations address the critical national need for rapid and timely insertion into operational systems. This August the FORTÉ (fast on-orbit recording of transient events) spacecraft was launched. FORTÉ carries an advanced payload, demonstrating enhanced electromagnetic-pulse detectors destined for Comprehensive Test Ban Treaty verification.

FORTÉ will perform a series of experiments to demonstrate real-time discrimination of electromagnetic pulses from natural and artificial backgrounds. In addition, FORTÉ will measure and characterize the natural and artificial radio-frequency background in which the operational sensor must function. The experiment will emphasize the distinguishing of electromagnetic pulses, primarily caused by lightning, within a noise environment dominated by continuous-wave carriers, such as TV and FM stations.

Optical sensors will complement the radio-frequency system in characterizing lightning events. A principal goal is a comprehensive understanding of the correlation between the optical flash and the very high frequency emissions from lightning. We will also make data available to researchers studying lightning and the ionosphere. The extensive database of the global distribution of lightning, as obtained from a satellite platform, can be used in studying, for example, the correlation of global precipitation rates with lightning flash rates and location. Researchers will combine the satellite data with those from simultaneous ground-based measurements as part of lightning physics studies. FORTÉ will also conduct ionospheric physics experiments to determine the effects of large-scale structures within the ionosphere on the propagation of broad-bandwidth radio-frequency signals.

Proliferation Detection Technology

To assist agencies responsible for operational missions, we develop and prototype instruments in numerous areas of technology.

Such instruments include novel sensors, processors and algorithms, and light detection and ranging (LIDAR) devices. These systems are designed to observe the signatures of NBC weapon proliferation—chemical effluents, thermal emission, multispectral optical-infrared signatures, starlight images, and radio-frequency transients—many of which must be extracted from enormous streams of data.

Nuclear Emergency Search Team

Los Alamos continues its leadership in the Nuclear Emergency Search Team (NEST). NEST activities have evolved in recent years from the traditional response to nuclear terrorism to that of a smaller, more rapidly responding team. The new concept was recently validated during two special deployments. The deployments were precautionary in nature, in the event of a terrorist attack involving nuclear materials. The team's primary goal was to support the FBI in the event of an incident involving a weapon of mass destruction.

Support for the International Atomic Energy Agency

Before Desert Storm, Iraq had a major, multi-billion-dollar nuclear weapon program. Although the program was poorly coordinated, it was intended to provide a limited number of deliverable fission weapons. Various official Iraqi reports required by the United Nations and the International Atomic Energy Agency (IAEA) have been deficient and deceptive; there is no doubt that as soon as international sanctions are removed, Iraq will reembark on a major nuclear weapon program. Production or acquisition of fissile material remains a major obstacle to the production of Iraqi nuclear weapons.

Los Alamos has been deeply involved in monitoring and assessing the status of Iraq's nuclear weapon program since late 1990. United Nations resolutions have authorized inspections of the Iraqi program and IAEA is responsible for continuing long-term monitoring of suspect, nuclear-related Iraqi activities, facilities, equipment, procurement, and personnel.

From the end of Desert Storm to the present, Los Alamos has received and reviewed information obtained from United Nations Special Commission and IAEA inspections. This includes first-hand information from Laboratory members of inspection teams and from the inspection of myriad Iraqi documents. Through information analyses and interagency projects, Los Alamos has updated policymakers in U.S. governmental organizations, such as the Department of State and DOE, and various intelligence agencies. We have alerted them to issues and prospects for Iraq's reconstituting its nuclear weapon program and specific monitoring needs and techniques.

Interactions with the Russians

Of the remarkable changes that have occurred in the world over the past twelve years, none are so dramatic as those in the Soviet Union. In the late 1980s, Soviet President Mikhail Gorbachev initiated policies of glasnost, or openness, and perestroika, or rebuilding. These policies began not only the opening of the Soviet Union for its own people and the world in general but also the events that led to the dissolution of the Soviet Union and the abandonment of single-party Communist rule.

In a context of rapid change, Gorbachev and President Reagan, intent on finally ratifying the Threshold Test Ban Treaty, pushed forward the negotiations on verification procedures for a 150-kiloton limit on underground nuclear tests. Although some hostility remained between the United States and the Soviet Union in 1988, those negotiations threw together nuclear weapon scientists from both countries, charged with developing joint experiments to prove verification technologies. The design and execution of the Joint Verification Experiments in 1988 required a degree of cooperation between nuclear weapon scientists from the two countries, cooperation that had never before existed.

In August and September of 1988, two underground nuclear explosions were fired, one in Nevada, called Kearsage, and one at the Semipalatinsk test site, called Shagan. Teams from the visiting country were allowed to place instrumentation for measuring yield close to the actual explosion points. The experiments were a success, the verification protocol was written, and the treaty was ratified in 1990.

Soon after the success of the Kearsage experiment, Laboratory Director Sig Hecker and Chelyabinsk-70 scientist Vadim Simonenko discussed the possibility of joint scientific experiments involving underground nuclear explosions. Such experiments never occurred, but the notion of working together in areas other than nuclear weapons took hold. Although the Threshold Test Ban Treaty was eclipsed by moratoria and finally by the Comprehensive Test Ban Treaty, scientists from the nuclear weapon laboratories of two countries showed they could cooperate on projects that reduce the risks of nuclear confrontation.

Over the past several years, Los Alamos has developed a special relationship with the Russian nuclear weapon design institutes. In addition to extensive scientific interactions, the Laboratory has led the organization of the program in laboratory-to-laboratory nuclear materials protection, control, and accountability (MPC&A) and other efforts that have had a direct stabilizing effect on the Russian nuclear weapon complex. An emerging danger is the possibility of nuclear proliferation resulting from the diffusion of knowledgeable experts from the nuclear design centers in the Russian Federation. Los Alamos also leads in addressing the potential for such proliferation and in facilitating the transition of nuclear weapon scientists into areas of nonweapon research and development. In addition to the highly successful materials control program, Los Alamos provides technical assistance to the Initiative for Proliferation Prevention, the International Science and Technology Center, and Nunn-Lugar-sponsored activities.

In the spring of 1994, the national laboratories, with Los Alamos in the lead, suggested a laboratory-to-laboratory approach to securing nuclear weapon materials with the Russian weapon institutes. Building on a foundation of trust and cooperation established through scientific collaboration, this approach proved remarkably successful. By the end of 1995, rapid progress was made at a number of Russian institutes. The best of Russian and American MPC&A technologies and methods were combined in an extensive demonstration that paved the way for widespread implementation throughout the Russian nuclear weapon complex.

Expansion of collaborative work with the Russians has dramatically improved the security of Russian nuclear materials. The collaboration includes work at additional nuclear weapon sites, as well as reactor fuel sites, and a program to safeguard nuclear material while being transported between nuclear facilities on rail cars. This highly successful approach to safeguarding nuclear materials has expanded to Belarus, Latvia, Ukraine, and Kazakhstan—four now-independent nations that formerly were part of the Soviet Union.

Flux Compression Experiments

During the past five years a strong scientific collaboration has flourished between researchers at Los Alamos and the team studying high-explosive-driven pulsed power at the All-Russian Scientific Research Institute of Experimental Physics at Sarov, Russia. The Russians have developed a technology of magnetic-flux-compression generators that use high explosives to compress an initial magnetic field and produce very high electrical currents. This highly advanced technology provides access to unique pressure and temperature regimes. Recent experiments have focused on the creation of metallic forms of noble gases through compression; the production of stable, warm, high-density plasmas as potential fusion targets; and the physics of materials in ultrahigh magnetic fields.

An electromagnet surrounded by explosives is detonated in a collaborative experiment by researchers including Los Alamos, Russian, Japanese, and German colleagues.

The View from Russia

Scientists at the Russian and U.S. nuclear weapon laboratories had long worked in the same areas of science and technology. Exchanging research data was absolutely barred, not to mention setting up joint projects. Articles published in science journals made it possible, of course, for the scientists to assess the achievements of their counterparts abroad; but the articles revealed something much more significant: each of the sides had unique expertise, and that expertise could effectively complement the expertise of the other side, to the benefit of world science. The total effort would have effects much greater than the sum of each individually.

Russia and the United States have similar approaches to the solutions of most scientific-technical problems. But more important, we have a similar understanding of the responsibility borne by nuclear scientists to their own people and to the entire world for the safety of the weapons they built for decades. Being professional in their work, they understand better than anyone else the dangers that attach to unthought-out decisions in the delicate business of nuclear weapons.

After the end of the Cold War, the Russian Federal Nuclear Center–VNIIEF and Los Alamos National Laboratory were actually the first nuclear institutes to launch the active process of collaboration.

The outstanding contribution to the establishment and successful expansion of cooperation between our institutes belongs, without a doubt, to the director of Los Alamos, Sig Hecker. He was one of the first to see that such cooperation was possible and to understand its real benefits. It takes a great deal of courage and persistence for one to go beyond stereotypes that have existed for decades.

Sig Hecker proved himself to be the kind of person, the kind of leader who not only was able to overcome the effects of past stereotypes but who also assembled a team of enthusiasts and guided it to cooperation with Russian nuclear laboratories.

In every stage of the development of our relations, we have felt the decisive influence of that calm, benevolent but firm leader and true scientist. Working meetings with him have always been fruitful, have provided new incentives for expanding the cooperation between VNIIEF and Los Alamos, and have been enjoyable.

Looking back, we are pleased at how quickly and how radically our notions of each other have changed. Before, they stemmed largely from the concept of confrontation and were based on mistrust and suspicion. Now we see that we are very much alike. We have, in fact, similar problems and the same responsibility, and our people even have the same sense of humor.

Today, we can point with confidence to the unquestionably positive results of our cooperation and to the benefits that cooperation has provided to VNIIEF and to Los Alamos. The multiplicative effect arising from the combination of our efforts in many areas of joint work has clearly exceeded expectations. And yet, what is perhaps the most valuable achievement is the atmosphere of true respect and growing trust that has been established between our scientists, an atmosphere whose existence is largely due to Sig Hecker himself.

Thus, the collaboration between VNIIEF and Los Alamos, which began with a modest exchange of visits in February 1992, has in five years developed into a serious area of activity for both institutes. The energy, sincerity, and personal charm of Sig Hecker have made a strong impression on Russian scientists and have become the component that has compelled many to believe in the very possibility of cooperation with U.S. colleagues.

Radii I. Il’kaev, Director
Russian Federal Nuclear Center
VNIIEF [All-Russian Scientific Institute of Technical Physics, Arzamas-16]

Environmental Stewardship

With the end of the Cold War, DOE has closed significant portions of the weapon production facilities. Resources for cleanup and waste management operations are now comparable to DOE defense spending. Los Alamos is aggressively cleaning up the legacy from fifty years of operations and managing waste from both ongoing and past operations; implementing waste minimization and pollution prevention in all operations; and applying science and technology to address local, regional, and global environmental issues.

We expect to complete cleanup of the nuclear legacy waste by 2006. Of the 2100 legacy sites of concern, cleanup is complete at over 1000 sites. The Laboratory’s goal is to reduce waste generation by 95 percent from 1993 levels by the year 2000 through the promotion of resource conservation, reuse, and recycling. Newly generated wastes will be safely and cost-effectively treated and disposed of to minimize the environmental impact and costs of the Laboratory's operations. We continue to shift away from a *compliance* mentality to a *sustainability* ethic. For example, instead of monitoring permitted outfall discharges to demonstrate compliance, the Laboratory is striving to eliminate these discharges and reuse the water. We also support the Laboratory's role as a responsible neighbor in northern New Mexico by inviting stakeholder participation in the planning of many of these activities.

In recent collaborations with the University of California at Los Angeles, at Santa Cruz, and at Berkeley, we successfully competed for funding in the DOE's Environmental Management Science Program. The purpose of this program is to develop the science base for new technologies that will address future environmental management needs of DOE. Specific research collaborations include polymer filtration, modeling and simulation of atmospheric processes, and LIDAR.

Transuranic Waste Characterization

Los Alamos has developed strategies that reduce both the cost of transuranic waste management by millions of dollars and the time needed to work off the waste backlog. Included are research and development initiatives to decrease problems with hydrogen generation in the waste that severely constrains shipments to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, and efforts to develop mobile characterization facilities that can be used cost-effectively at small sites to prepare material for shipment.

Of the three DOE sites that contain significant amounts of transuranic waste, only Los Alamos will be approved by DOE in 1997 to certify waste. This is a major milestone for the opening of WIPP, because the Environmental Protection Agency will not review DOE's application to open WIPP until at least one site is authorized to certify waste for disposal there.

Department of Defense Programs

Los Alamos has long supported national security interests and has contributed significantly to DoD, since our unique capabilities and nonaligned status allow us to support key DoD technology needs and requirements for conventional defense. Funding from DoD leverages the substantial DOE investment in science and technology at the Laboratory to DoD's advantage, while contributing to our core defense mission. For example, in 1987 nearly one-fourth of the Laboratory's funding came from DoD through the Strategic Defense Initiative Organization. In partnership with DoD and industry, we developed innovative, speed-of-light weapons—the free-electron laser, neutral particle beam, and nuclear directed-energy devices—for defense against attack by ballistic missiles. Although those efforts are no longer active, the substantial technology base they generated here has spawned three new efforts at the Laboratory—APT, the national spallation neutron source, and accelerator transmutation of waste.

Today, DoD programs at the Laboratory span the range of high-performance computing, modeling and simulation, advanced conventional munitions, beams and sensors, advanced materials, and biotechnology. Successful partnerships with the DoD laboratories, industry, and academia have led to rapid deployment of innovative, affordable technologies such as LIDAR for the long-range detection of biological agents; innovative armor technologies to protect air crews flying into Bosnia; and advanced, conventional multimode warheads to allow flexible attacks against various targets. In 1994 Los Alamos hosted a conference to address the emerging threat to the military of weapons of mass destruction, including NBC weapons. The conference led to legislation creating the DoD Counterproliferation Support Program. A similar conference in 1996, which focused on concerns about international terrorists using weapons of mass destruction, resulted in the Defense Against Weapons of Mass Destruction Act of 1996 (Nunn-Lugar-Domenici legislation).

Current and projected investments in Los Alamos by DOE to support science-based stockpile stewardship will result in an unparalleled array of people skills, facilities, diagnostics, and analytic capabilities that can address many of the demanding technological challenges facing DoD in the twenty-first century. This array and the rapid downsizing of DoD's science and technology infrastructure will make Los Alamos the technology provider of choice for certain DoD requirements to support this country's national security needs in the next century.

CIVILIAN SCIENCE AND TECHNOLOGY

Los Alamos National Laboratory's identity and international reputation rests upon the quality of the science and technology applied to its missions and upon its sustained performance in satisfying national needs. Programs in civilian science and technology, supported by other DOE offices such as the Office of Energy Research, and work for other federal agencies in the civilian sector help support capabilities essential to our national security missions.

These activities also integrate our scientists into the broader scientific and technical community, helping to ensure the quality of the Laboratory's work. We interact strongly with university researchers, and we work in partnership with industry with increasing frequency, both to meet mission requirements and to compare our science and technology with the best in the world.

Whether in basic nuclear research, the human genome or other bioscience programs, materials research and development, energy technologies, high-performance computing, space, or the application of Laboratory-developed technologies to commercial uses, activities in civilian and industrial research and development serve important national needs while helping to maintain the vitality of the Laboratory.

As we apply the core competencies developed for our national security responsibilities to civilian needs, we seek to reinforce the reputation of the Laboratory for quality science and technology. In the past few years we have completed the transition of the Los Alamos Meson Physics Facility, a nuclear science center established in the 1960s, to a nationally recognized neutron science center. We are frequently recognized for our application of high-performance computing to complex scientific problems and for materials research and development. We are also expanding our efforts in the biosciences, particularly in structural biology, with the application of neutron scattering.

NUCLEAR AND ADVANCED MATERIALS

The Laboratory's ability to characterize and evaluate materials for the stockpile and to accept manufacturing responsibilities rests on a foundation of expertise in materials science, including the science of nuclear materials. The performance of a device, whether it is a nuclear weapon or an automobile, depends on the properties of the materials or combination of materials of which it is made. Our research includes studies of the relationships among those properties, the structure of the materials, and the processes that produce the materials. The capabilities developed in this work are crucial for solving materials performance issues relevant to meeting the Laboratory's mission goals.

Materials capabilities are also a key to the Laboratory's successful partnerships with industry, including those involving high-temperature superconductors, fuel cells, directed-light fabrication, microwave processing for advanced materials, composite materials, thermoacoustics and cryogenic technologies, conducting polymers, and sensor technologies.

Fuel Cells

Los Alamos is an established world leader in the technology of the polymer-electrolyte fuel cell. This fuel cell converts hydrogen or hydrogen-rich fuel directly to electricity at low temperature, produces no emissions, and exhibits very high energy conversion efficiencies. Los Alamos researchers have made key contributions during the last ten years, converting this fuel cell from a complex, costly system to one that is both technologically and economically viable. Our research has dramatically cut the requirements for precious-metal catalysts while maintaining high performance, replaced expensive machined graphite with nonmachined composite or metal hardware, and resolved fuel sensitivity problems in the operating cell. In addition, we have collaborated extensively with U.S. manufacturers to develop fuel-cell applications in stationary power generation and in electric vehicles that would ensure a cleaner environment and help lower U.S. dependence on oil imports.

High-Temperature Superconductivity

Los Alamos has made important contributions to superconductivity research since the 1950s, when low-temperature physics was vital to early weapon development programs. In the 1970s, Laboratory scientists collaborated with industry on a superconducting, magnetic-energy storage system for moderating electric power fluctuation. Building on this legacy and over thirty years of materials science and applied physics research, Los Alamos established the Superconductivity Technology Center in 1988. The center is one of three DOE sites for establishing the technology base that U.S. industry needs to develop commercial applications of the high-temperature superconducting materials first discovered in 1987.

Last year Los Alamos researchers developed a *super tape* capable of carrying a current density of more than 1 million amperes per square centimeter at the temperature of liquid nitrogen. The current density is much greater than that of any other flexible high-temperature superconducting tape yet developed. Using a process called ion-beam-assisted deposition, researchers deposited a layer of cubic zirconia, carefully aligned, on top of a flexible strip of nickel and, using a pulsed laser, a superconducting ceramic of yttrium-barium-copper oxide on top of the cubic zirconia layer. The precise orientation of the layers obtained through this deposition process is necessary for high current to flow through the superconducting materials.

A Los Alamos researcher demonstrates the flexibility of a length of high-temperature superconducting super tape.

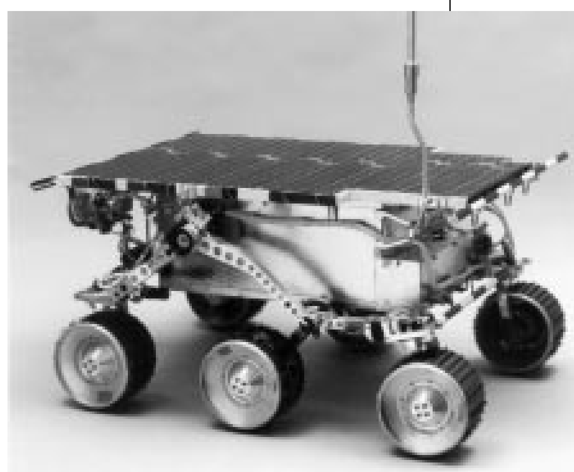
Recently, the Superconductivity Technology Center partnered with 3M, Southwire Company, and Oak Ridge National Laboratory to explore methods for continuously processing long lengths of the super tape. The tape could be used in prototype superconducting motors, generators, power cables, and other electric devices that might be introduced shortly after the turn of the century.

Actinide Chemistry

Los Alamos plays a major role in actinide science within the DOE complex and has redefined actinide materials characterization and speciation. We have applied a combination of new spectroscopic techniques, synthetic routes, and theory and modeling methods in order to guide actinide science—from bulk materials to interfaces and molecular chemistry. These advances in analytical chemistry and analysis will have applications in environmental actinide science, process chemistry, and plutonium residue stabilization. A new branch of the Glenn T. Seaborg Institute for Transactinium Science at the Laboratory will address national and international needs for quality science and technology and improve actinide education and institutional collaborations.

Pathfinder Mission to Mars

The Pathfinder mission to Mars began with a launch in December 1996, which was followed by a successful landing on July 4, 1997, with the subsequent worldwide broadcast of pictures of the barren, rocky landing site. The rover Sojourner contains radioisotope heat units fabricated at the Laboratory's plutonium facility. The plutonium-238 oxide heat sources provide thermal power to batteries and electronics, which must operate during temperature excursions below –400 degrees Celsius. The contribution to the Pathfinder mission serves as a reminder of the Laboratory's long association with the space program and of its role as a supplier of long-life, high-reliability, heat sources that have made deep-space exploration possible. During the past twelve years Los Alamos has fabricated radioisotope-fueled heat sources for the Galileo mission to Jupiter, the Ulysses mission to the sun, and the Cassini mission. The Cassini mission begins in October 1997, and in 2004 it will be in position to embark on a lengthy study of Saturn and its moon, Titan.



A radioisotope source provided by Los Alamos warms electronic systems on the Mars rover Sojourner.

National High Magnetic Field Laboratory

In 1990 in an open competition, the National Science Foundation chose a consortium composed of Los Alamos, Florida State University, and the University of Florida to establish a new national user facility for high-magnetic-field research—the National High Magnetic Field Laboratory (NHMFL). In its role Los Alamos established the nation's first pulsed-magnetic-field user facility that provides fields from 40 to several hundred tesla, surpassing magnetic fields available anywhere in the world. This facility is the basis for a national and international user program in high-magnetic-field research and has significant participation from the University of California.

The Los Alamos pulsed-magnetic-field facility features the world's most powerful magnet, a 60-tesla, quasi-continuous magnet that can operate at peak field for 100 milliseconds, powered by our 1.4-gigawatt generator. Through a collaboration between DOE and the National Science Foundation, we are designing the world's first reusable 100-tesla magnet. The NHMFL is contributing directly to other Los Alamos efforts, such as high-temperature superconductivity and plutonium research, and is a cosponsor of the joint U.S./Russian series of ultrahigh magnetic field experiments.

Theory, Modeling, and High-Performance Computing

A major contributor to the Laboratory's ability to formulate and solve complex technical challenges rests on combining fundamental theory with the power of high-performance computing. It builds on fifty years of collective learning and experience, combining experimental programs with numerical approaches to solving highly complex, nonlinear systems. Theory, modeling, and high-performance computing provides a cost-effective approach to developing physical insight and intuition and enables us to fine-tune solutions before or often without building expensive facilities. By combining analysis and numerical simulations with experimental validation, we can incorporate relatively inexpensive numerical experimentation into system designs and decision making. Efforts at the Laboratory involve virtually all science and engineering disciplines.

Universal Scaling Laws

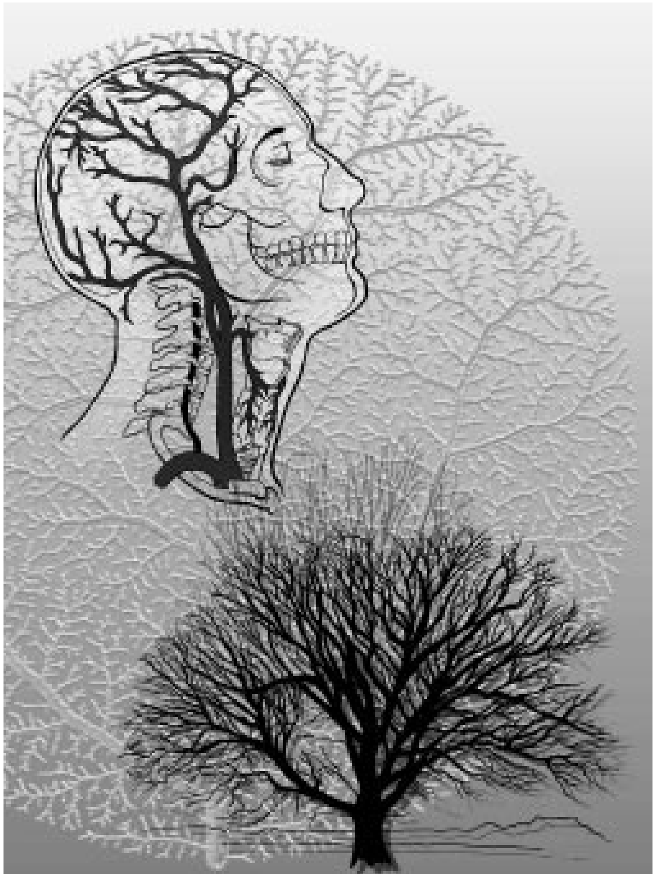
A recent collaboration with the University of New Mexico has revealed simple and systematic empirical scaling laws that relate many organic features that vary with size. These include fundamental quantities like metabolic rate, time scales such as life span, and heart rate and size. It is a remarkable fact of biology that all these features can be expressed as simple power-law relationships with exponents that are multiples of one-fourth. Furthermore, the relationships are valid for almost all forms of life and over as many as 23 orders of magnitude, from the mitochondria within the cell to the macroscopic whale and giant sequoia.

The origin of these scaling relationships, in particular why the exponents are always simple multiples of one-fourth, has been a long-standing fundamental problem in biology. Recently, we have shown that these laws follow from the fundamental observation that complex structures are constrained and ultimately limited by the rate at which essential resources that sustain them can be supplied.

Complete quantitative descriptions and all the known scaling laws can be derived by assuming that organisms have evolved to minimize energy use and by invoking the idea of a fractal-like branching network that reaches every basic unit in the organism. Cells in the circulatory system of mammals and leaves in the vascular system of plants are examples of these basic units. The model suggests possible hints for understanding related problems such as energy dynamics within the cell, the question of aging, and the scaling of animal drug testing. The basic set of ideas is universal and can, in principle, be extended to ecology, economics, river systems, urban development, corporate structures, and computer networking.

Knowledge Discovery

A new field in computer science, called knowledge discovery, has emerged to address the immense



Universal scaling laws relate the fractal nature of branching through fundamental biological processes to structures as diverse as trees and circulatory systems.

problems of extracting knowledge from vast amounts of data. Scientific, business, and government communities are faced with petabytes (10^{15} bytes) of heterogeneous data, collected at rates sometimes exceeding gigabytes per hour. This information overload is ubiquitous: consider a weapon scientist's frustration at browsing through thousands of old scanned test documents searching for an explanation of a subtle effect, a heath care investigator's laboring through 600 million claim records looking for a fraud scheme that has been intentionally disguised and hidden, or a Pentagon military assessment analyst's trying to make sense of thousands of satellite images.

Knowledge discovery requires expertise in algorithm development, high-performance computing technology, computer security, mathematics, databases, statistical pattern recognition, and machine learning—all areas in which Los Alamos excels. Advances in knowledge discovery benefit many Laboratory activities, from extracting critical information from the repository of nuclear testing data to assisting nonproliferation experts in distilling volumes of intelligence data. Advanced information technologies are necessary for U.S. economic advancement, but the nation's increasing reliance on those technologies is a growing vulnerability likely to be exploited by adversaries. Information warfare attacks on critical targets in the national information infrastructure, such as the national air-traffic control system, regional power grids, and the command, control, and communications infrastructure of the military, are fast-growing threats that can be addressed by knowledge discovery technology.

Knowledge discovery activities at Los Alamos have already proved their value for highly visible national security needs such as the detection of income tax and Medicare fraud, DOE document declassification, and the FBI Fingerprint Project. Those successes have increased interest from several other state and federal agencies, both for deliverable technology and collaborative efforts.

Quantum Computation

A quantum computer is the natural extension of current classical devices taken to the atomic scale. It stores bits in an analogous fashion, using atomic states. In addition, a quantum computer can take advantage of nonclassical phenomena, such as the superposition of quantum states, which allows quantum computers to process exponentially more information per cycle.

Quantum states are significantly more sensitive to the environment than are classical representations of bits. We have established that noise poses no fundamental obstacle to scalable quantum computation. Experiments are underway to explore quantum computation with ion traps and nuclear magnetic resonance. Although we anticipate applying this technology to a full spectrum of computationally intensive problems, current efforts focus on the immediate applicability of quantum computers to code breaking. Because of the wide use of breakable codes for secure communication and financial transactions, the impact of quantum computers on national security and the economy could be enormous.

Lattice Gas Algorithm

In the past decade, the lattice gas computation method has evolved from a toy mathematical model to a powerful research tool for modeling complex fluid flows, particularly those with complicated boundary conditions. It is now used by oil companies to enhance oil recovery, to design chemical processors, and to improve multiphase oil transport through pipelines. This method was the central feature of two R&D 100 Awards, and dedicated hardware has been designed to implement the algorithm. It is now proving especially powerful in modeling turbulence and biological cell formation and in simulating the cardiovascular and digestive systems for diagnostics purposes. The latest version of this method, called the lattice Boltzmann method, has solved multiphase problems quickly and accurately in a way that can easily be run on the latest parallel computers. Active research is now extending the method to granular flows, such as those of sand and coal, and to extrusion processes of interest to the plastics industry.

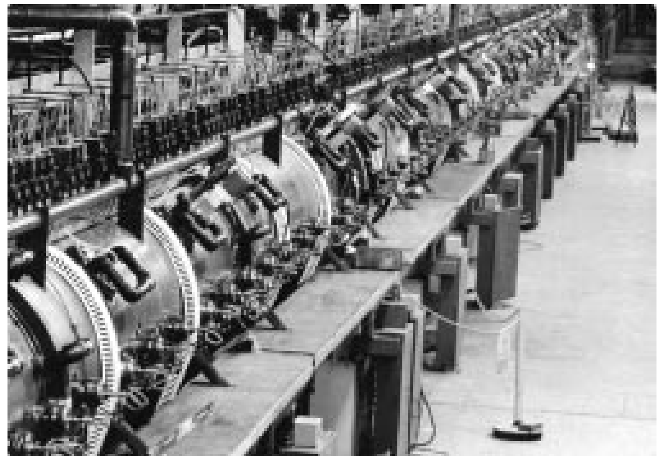
Nuclear Science, Plasmas, and Beams

The Los Alamos Meson Physics Facility (LAMPF) was the flagship of the U.S. nuclear physics program for more than twenty years and provided one of the richest programs of nuclear science ever experienced by this community. The beams of pions, muons, neutrinos, protons, and neutrons produced at LAMPF with its high-intensity, 800-million-electron-volt primary proton beam were unsurpassed in the world. Pions gave us a window into the nucleus that allowed us to probe new topics, such as neutron distributions within the nucleus, how two nucleons are correlated in the nucleus, and the compressibility of nuclear matter. The intense beams of muons allowed high-sensitivity measurements to provide new insights into the Standard Model and its extensions. LAMPF not only was at the forefront of nuclear science, it also produced some of the best results on muonium in atomic physics and engaged in an active pion cancer therapy program with the University of New Mexico. The LAMPF beams were used for radiation damage studies, muon-catalyzed fusion studies, and a broad array of weapon physics measurements.

In 1995, with the closeout of the nuclear physics user program and in response to the increased national need for neutrons, Los Alamos refocused the mission of its linear accelerator complex. The new direction called for developing and using spallation neutron sources for both basic and applied research. The accelerator complex is now called the Los Alamos Neutron Science Center (LANSCE) and includes the high-power proton linear accelerator, the Manuel Lujan Jr. Neutron Scattering Center, the proton storage ring, and the Weapons Neutron Research facility. A variety of experimental areas are available at the Lujan Center.

LANSCE provides neutrons in support of the DOE science-based stockpile stewardship and management activities as described previously, as well as a national user program. The DOE Office of Basic Energy Sciences supports the national user program, in which neutron spectrometers are available to universities, industry, and other federal laboratories through open, peer-reviewed access. The users and in-house staff work in materials science, engineering, geoscience, chemical sciences, and structural biology.

With the conversion from LAMPF to LANSCE, two major facility upgrades are in progress. A reliability improvement project will provide more reliable and convenient operations, allow LANSCE to extend its annual run cycle to eight months, and increase the Lujan Center beam current from 70 to 100 microamperes. Enhancement of the short-pulse spallation source includes an accelerator upgrade and new instrumentation and will ultimately provide LANSCE performance levels equal to or better than the best pulsed spallation source in the world—the ISIS facility in the United Kingdom. The accelerator upgrade includes a new ion source, a new linear accelerator injector system, and an upgraded radio-frequency buncher to allow delivery of 200 microamperes of beam to the Lujan Center. Up to seven new, advanced neutron-scattering spectrometers will be installed at the Lujan Center. Built by academic-industrial-federal laboratory teams, the spectrometers will be used by the research programs of both the teams and the national user community.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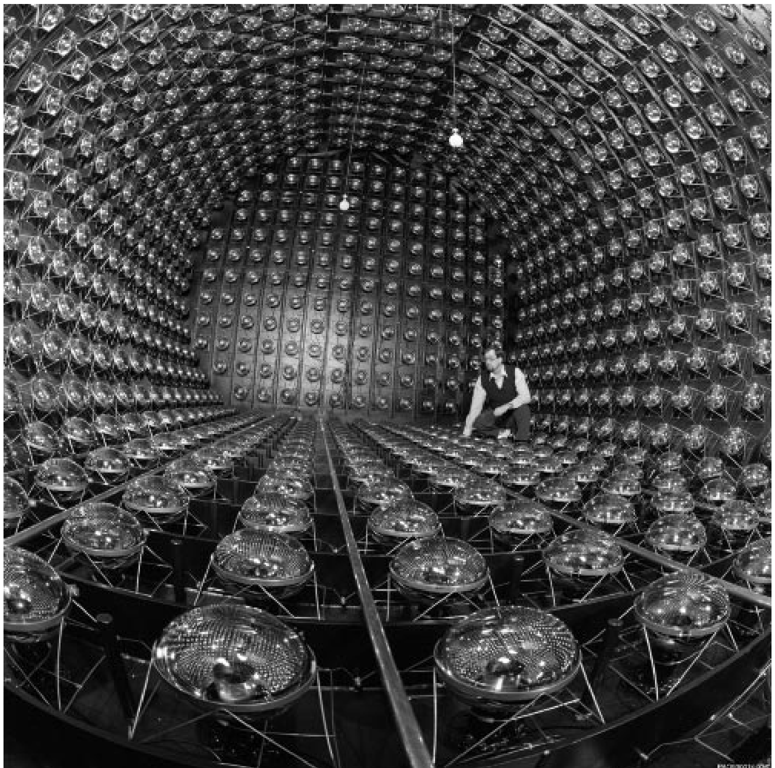
Main accelerator cavities at LANSCE accelerate the proton beam to 800 million electron volts. Neutrons produced by spallation when this beam strikes a tungsten-lead target are used to probe the structure of materials.

Neutrino Science at Los Alamos

In 1932 Wolfgang Pauli predicted the existence of a nearly massless neutrally charged particle that must exist to explain the features of nuclear beta decay and called it the neutrino, using the name suggested by Enrico Fermi. Because of its very weak interaction with normal matter, the neutrino was not directly observed until Frederick Reines and the late Clyde Cowan, Jr., who were both then at Los Alamos, detected the elusive particle in experiments they conducted in the late 1950s. In 1995 Frederick Reines received the Nobel Prize for Physics for this discovery, along with Martin Perl for his discovery of the tau lepton.

When LAMPF was commissioned in 1972, it produced a high-intensity beam of protons at energies sufficient to create pions (short-lived, subatomic meson particles). Neutrinos are a natural product of pion decay. The LAMPF beam had numerous unique properties that made it an almost ideal source of neutrinos. Even before LAMPF started up, a blueprint for the neutrino program was developed during a workshop that has served the facility well for over twenty years. Four experimental goals were outlined: to deduce the form of the lepton family-number laws, in particular, electron- and



A researcher examines the photomultiplier tubes in the liquid scintillator neutrino detector. In operation, the tank is filled with high-purity mineral oil.

muon-number conservation laws; to measure the scattering cross section between electrons and electron neutrinos; to measure neutrino interaction cross sections relevant to solar neutrino experiments; and to search for neutrino oscillations.

In total, six major experiments have used the LAMPF neutrino source. A highly successful experiment examined the manner by which muon-family number and electron-family number are conserved. Another measured scattering cross sections between electrons and electron neutrinos, ruling out constructive interference between neutral and charged-current interactions and confirming that electron neutrinos have scattering cross sections in electron-rich matter that are different from those of muon or tau neutrinos. In a series of experiments, including the ongoing liquid scintillator neutrino detector (LSND) experiment, scientists are searching for evidence of neutrino oscillations in which one type of neutrino is converted to another type of neutrino. If observed, neutrino oscillations would have profound implications for the Standard Model of electroweak interactions and our current understanding of cosmology. In 1995, in part with University-Laboratory funding, the LSND team published data showing candidate events that are consistent with neutrino oscillations. Since then, the collaboration has reported additional data that provide stronger evidence for neutrino oscillations. Ensuing interest from the scientific community prompted a proposal for a next-generation experiment at Fermi National Accelerator Laboratory to pursue this exciting result. Finally, an ongoing experiment is measuring scattering cross sections for electron neutrinos on chlorine-37 and iodine-127 that will help in calibrating detectors for solar neutrinos.

Earth and Environmental Systems

The need to understand the transport and fate of radioactive material associated with atmospheric testing introduced Los Alamos to earth and environmental sciences. The scope of this work broadened considerably as a result of the Limited Test Ban Treaty, signed in 1963, which required that all nuclear tests be contained underground. From that early beginning, the scope of Los Alamos research in earth and environmental sciences has evolved and today includes basic and applied research in areas such as atmospheric, ocean, and climate sciences; geophysical fluid dynamics; ecological sciences; geochemistry; seismology; hydrology; and drilling and mining technology. In recent collaborations with several University campuses under DOE's Environmental Management Science Program, we are developing the science base for new technologies to address future national environmental management needs.

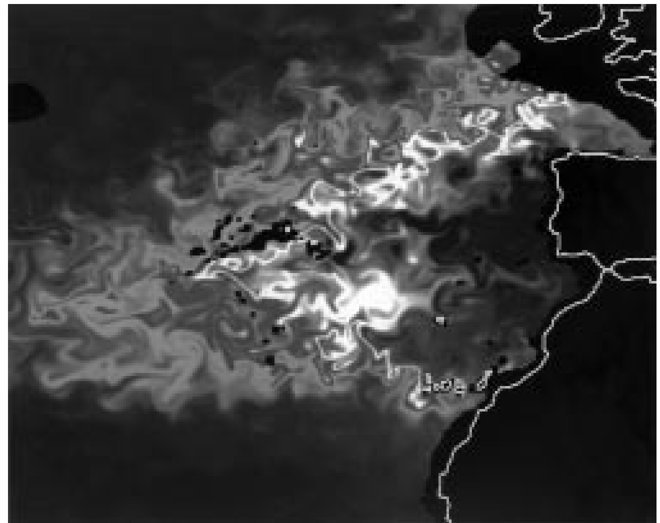
Climate Modeling—Adapting to the Nation's Changing Needs

Climate modeling at Los Alamos began in 1979 with the objective of developing the capability to address energy-related climate issues, such as global warming caused by excessive carbon dioxide in the atmosphere. In 1983 the newly developed and relatively crude simulation capability was applied to the subject of nuclear winter, the hypothetical cooling of the earth's surface by a thick layer of smoke from burning cities after a nuclear war. The Los Alamos findings, published in 1985 and 1986 in *Science* and the *Journal of Geophysical Research,* clearly portrayed changes in the earth's atmosphere and climate that might occur in the aftermath of a major nuclear war.

As the Cold War came to an end, fear of nuclear war and concerns about nuclear winter subsided. However, in 1990 a new crisis arose, the invasion of Kuwait by Iraq with the subsequent ignition of massive oil-well fires throughout Kuwait. The atmospheric model that was developed for nuclear winter was immediately used to assess the potential atmospheric and climatic impacts of smoke from those fires. Using estimates from Sandia National Laboratories of smoke production from the burning oil wells, Los Alamos scientists concluded that no significant climate effects would occur, as indeed, they did not.

During the 1980s the importance of the oceans in controlling long-term variations in climate was recognized. However, development of ocean models lagged far behind that of atmospheric models. Eddies in the ocean are about ten times smaller than eddies in the atmosphere and hence are more expensive, computationally, to resolve. In 1991 DOE started the Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) program to address the applicability of massively parallel computers to climate modeling. Under the CHAMMP program, Los Alamos developed the Parallel Ocean Program (POP). POP was used for the highest-resolution global ocean and North Atlantic Ocean simulations ever made, both of which compare favorably with observations.

In collaboration with scientists at the National Center for Atmospheric Research, Los Alamos scientists have coupled POP to an atmospheric model, to a new sea ice model developed at the Laboratory, and to the center's land surface model. The combined model will be used to study natural variability in the climate system and issues such as global warming—so we have arrived at our original objective. The model may also be used in a University-Laboratory collaboration on modeling and prediction of water resources in California and the western United States.



Salinity contours at a depth of 1 kilometer, showing high-resolution (10-kilometer) eddies resulting from the flow of high-salinity Mediterranean water through the Strait of Gibraltar.

Yucca Mountain Project

The United States and most other nations have selected the geologic repository as the preferred option for disposal of spent fuel and certain other types of high-level nuclear waste. Yucca Mountain, Nevada, is the candidate site for the U.S. repository. Los Alamos is a member of a team composed of twenty-two organizations providing DOE with the scientific research and engineering analysis needed to evaluate Yucca Mountain as a repository. Results of several years of work by Los Alamos scientists include a volcanic-hazards analysis, a three-dimensional model of subsurface mineral distributions, cross-hole tracer testing, numerical predictions of radionuclide transport, and the coordination of underground experiments in a five-mile tunnel beneath Yucca Mountain. The capabilities developed through the Yucca Mountain research have widespread application. Japanese scientists, for example, have requested our assistance with volcanic-hazards analysis of their repository program.

Wild-Land Fire Behavior

Wildfires are a threat to human life and property, yet an unavoidable part of nature. We have used a transport formulation to produce a model that can represent complex fire behaviors. The transport approach allows us to represent complex environments such as transition regions with nonhomogeneous vegetation and terrain. Significant fine-scale details are described by dividing fuel, wind, and gas concentrations into mean and fluctuating parts, as in turbulence transport modeling. With this model the essence of wildfire propagation can be simulated, including such features as acceleration on upsloping terrain, deceleration of fronts on downslopes, canyon jumping, and crowning in the presence of high winds.

The wild-land fire simulation accurately depicts complex fire behavior such as canyon jumping.

Remote Sensing of Volcanoes

Los Alamos has a strong interest in remote-sensing technologies because of their applications in global climate and atmospheric change, environmental pollution monitoring, proliferation detection, and earth sciences. Quantitative measurement of the composition and flux of volcanic gases, for example, is fundamental to an understanding of deep-earth processes, eruption forecasting, atmospheric evolution, and climate impact. Since 1975, volcanic eruptions have caused the deaths of approximately 30,000 people and much destruction of property. Scientists know that the relative proportions of major volcanic gases change before and during eruptive events. Los Alamos researchers are using LIDAR techniques to measure the absolute abundance of sulfur dioxide and the relative abundance of other constituents such as hydrogen chloride and hydrogen fluoride in volcanic plumes. The remote sensing capability of these instruments means that the monitoring stations can be located at safe distances from the volcanoes. Monitored volcanoes include Ruapehu and White Island in New Zealand and Popocatépetl near Mexico City, where up to 60,000 tons of sulfur dioxide are emitted every day. For areas like Mexico City, with its 20 million inhabitants, early warning could be crucial for successful evacuation and preparedness.

Bioscience and Biotechnology

We have conducted life sciences research at Los Alamos since the founding of the Laboratory, when the responsibility for studying the effects of ionizing radiation in biological organisms was recognized. Early research focused on whole-animal studies and resulted in setting rational dose limitations for radiation workers. As the research became more mechanistic, Los Alamos developed capabilities in radiation biology, cellular biology, cytogenetics, and analytical techniques such as flow cytometry, which originated at the Laboratory. With the advent of recombinant DNA (deoxyribonucleic acid) technology in molecular biology, Los Alamos was well positioned to undertake a major role in one of the most exciting projects in contemporary science—sequencing the human genome. Currently, the study of the relationship between structure and function of biological macromolecules is being extended by the development of new facilities, such as a neutron crystallography station at the Manuel Lujan Jr. Neutron Scattering Center. Bioscience programs at the Laboratory keep Los Alamos in the forefront of the development of new measurement technologies and applications.

The Human Studies Project

The Laboratory's Human Studies Project Team was formed in late 1993 to address questions raised by the Secretary of Energy regarding the ethics of human radiation experiments at Los Alamos from the era of the Manhattan Project through the early 1960s. Widespread publicity of plutonium injection experiments and other human radiation experiments called Laboratory credibility and integrity into question. Laboratory management established the team as part of a major effort to achieve public trust through the open sharing of experiences and information and to actively turn the negativity that gripped the media, the public, and many Laboratory employees into a positive force. The Laboratory and the public would gain perspective from a thorough review of both the science and the ethics of the human radiation experiments.

The initial focus of the project was a comprehensive review of all available documents and data. Newly discovered documents were reviewed on a weekly basis, decisions were made about editing material that was confidential under the privacy act, and the documents were released to the public. The team provided an extensive historical review of radiation protection practices and the human experiments, and an examination of the current knowledge of radiation and risk. The team released over 1600 documents related to human studies and historical Laboratory activities—an extraordinary accomplishment.

Some of the facts of the plutonium injection experiments are difficult to accept. We cannot hide behind the fact that during the time of the Manhattan Project, the need for data that would allow researchers to interpret the results of accidental occupational intakes of plutonium was immediate. Neither does the lack of evidence that the injectees were physically harmed excuse the actions. We now realize that the patients who were injected with plutonium may not have fully comprehended what was being done to them; the information was even withheld from several of the participants when they were called back years later so that additional excretion data could be gathered. The President's Advisory Committee on Human Radiation Experiments concluded that the injectees and their families had been ethically wronged. Not many among us would disagree with that conclusion.

Flow Cytometry

During the past decade, the role of flow cytometry, a technology developed at Los Alamos in the 1960s for cellular analysis, has vastly expanded. Flow cytometry is a technique that allows analysis of single fluorescent particles. Early work focused on the analysis of mammalian cells such as blood cells. Drawing upon sensitive fluorescence detection techniques, Los Alamos investigators have developed methods for analyzing subcellular components such as chromosomes and for detecting single fluorescent molecules.

Chromosome analysis and sorting by flow cytometry was the necessary first step for the construction of chromosome-specific recombinant DNA libraries that laid part of the foundation for the Human Genome Project and continues to play an important role in providing sources of DNA for sequencing. The achievement of single-molecule detection has opened up a completely new regime of applications of sensitive fluorescence detection, including two applications related to the Human Genome Project: DNA sequencing and DNA-fragment-size analysis. DNA-fragment-size analysis, which accomplishes the measurement in minutes rather than the hours typical for gel electrophoresis and with improved accuracy, received an R&D 100 Award in 1997.

Parallel developments have resulted in new, more rapid chromosome sorting to meet the demands of the Human Genome Project and in the capability of measuring fluorescence lifetimes on a cell-by-cell basis by phase-sensitive flow cytometry. Since 1983 the National Flow Cytometry Resource, has stood as a cornerstone of the developments in flow cytometry. The 1997 annual course in flow cytometry attracted fifty-five participants from seven countries and included three participants from the University of California.

Structural Biology

Neutrons are a powerful probe of molecular structure because they are neutral particles that interact with atomic nuclei and can deeply penetrate condensed matter. Using small-angle neutron-scattering instrumentation at the Manuel Lujan Jr. Neutron Scattering Center, Los Alamos scientists are studying the structures of biological macromolecules (proteins and DNA) and their interactions in solution. By substituting deuterium for hydrogen in specific components, researchers can study the component structures in a functioning biomolecular system in solution. Using these approaches, we study how proteins function and communicate at the molecular level to achieve coordinated activity. Examples include muscle contraction and the recognition and repair of damaged DNA. In the future we will probe biological structures at higher resolution, using a new protein crystallography instrument that is under construction at the Lujan Center.

Human Genome Project

The Human Genome Project is one of the most exciting and challenging research programs in the biological sciences. Our early studies of radiation effects evolved into investigations of the structure and function of mammalian chromosomes, including the regulation of gene expression. Those efforts brought together molecular biologists, cell biologists, and cytogeneticists interested in human genome organization. The development of flow cytometry at Los Alamos coupled with recombinant-DNA technology was directed toward construction of chromosome-specific DNA libraries. The National Laboratory Gene Library Project, initiated in 1983, catalogued recombinant DNA libraries from individual human chromosomes isolated by flow cytometry. Over 6000 copies of these libraries have been distributed to universities, hospitals, and research institutions worldwide. The libraries have played a crucial role in the isolation of several major human disease genes, and they form the basis of many of the existing high-resolution physical maps of chromosomes.

The combination of the Gene Library Project, capabilities in molecular biology and flow cytometry, and GenBank (a national genetic-sequence database) resulted in the DOE selection in 1988 of Los Alamos as one of the first Centers for Human Genome Studies. The centers were charged with leading a national effort to map, sequence, and analyze the human genome. Research at Los Alamos includes cell biology, cytogenetics, flow cytometry, molecular biology, informatics, and robotics.

Researchers have achieved notable technical accomplishments in the Los Alamos Human Genome Project during the last decade. In addition to the National Laboratory Gene Library Project, they have constructed a robot that can reliably handle the millions of DNA clones necessary to map and sequence chromosomes; developed methods to detect and analyze single, labeled DNA molecules; and identified and characterized the base sequence of the human telomere (the end of a chromosome). In 1994 Los Alamos researchers completed an integrated physical-genetic-cytogenetic map of human chromosome 16. This map, which is larger than any previous chromosome map and which has uncovered the physical location of numerous genes previously unassigned to any chromosome, provides a high-resolution set of overlapping clones that serve as templates for DNA sequencing.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Flow cell in a DNA fragment-sizing apparatus. The microscope objective behind the cell collects fluorescence emitted by tagged DNA fragments.

The Laboratory's Center for Human Genome Studies, with similar units at Lawrence Livermore and Lawrence Berkeley National Laboratories, is part of the DOE Joint Genome Institute. The units of the institute are cooperating on efforts in high-throughput DNA sequencing.

Dynamics of HIV Infection

Although today's potent antiviral drugs can remove 99 percent of the human immunodeficiency virus (HIV) from the blood plasma of HIV-infected persons within a few weeks, a cure for this infection is not yet at hand. Mathematical modeling studies at Los Alamos have helped uncover the dynamics of HIV infection in vivo. The studies have shown that HIV replication occurs at enormous rates, with at least 10 billion virus particles produced and cleared from the body each day, and that productively infected T-cells are eliminated from the body with a half-life of one to two days. However, other infected cells may continue to produce the virus for longer periods. These factors drive the dynamics of HIV infection and its response to antiviral drugs.

Collaborators at Rockefeller University recently studied eight HIV-infected patients who were treated with a combination of antiviral drugs and observed behavior similar to that predicted by the Los Alamos model. After an initial rapid decline of HIV in the patients' plasma, lasting approximately two weeks, the virus declined at a much slower rate. After eight weeks of treatment, the virus was undetectable in plasma by current assays. The research suggests that the second, slow-elimination phase of HIV is caused by virus release from long-lived tissue cells. In addition, even after elimination of HIV from these types of cells, viral genomes are still present in latently infected T-cells, and unknown sanctuaries might exist from which new infections could erupt if treatment were stopped. Modeling results suggest that it may therefore take two to three years or more of aggressive treatment to eradicate HIV from the body completely.

University Partnerships

The Laboratory is active in programs for faculty, postdoctoral participants, graduate students, and undergraduate students. Another form of partnership with the University of California relies on funds from a portion of the University's management fee.

University Students and Faculty at the Laboratory

In addition to offering the science education programs, which are discussed elsewhere in this report, the Laboratory welcomes about 1400 undergraduate and graduate students each year as research interns who work on leading-edge problems with Laboratory scientists and technicians using state-of-the-art facilities. About 150 of the graduate students conduct thesis work at the Laboratory. Los Alamos also has about 350 postdoctoral participants (from an applicant pool of approximately 2500) at any given time. Affiliate agreements—currently about 400—with faculty and students from academic institutions provide opportunities for collaborative research.

A student at the Laboratory works on a state-of-the-art project.

University of California Directed Research and Development

Los Alamos uses funds from the University's management fee to enhance collaborations with University of California campuses and New Mexico universities and to strengthen selected focus areas important to the Laboratory. University of California Directed Research and Development (UCDRD) funding supports four types of activities: The Collaborative University–Los Alamos Research (CULAR) program funds small collaborative research projects between Laboratory and University researchers. The Visiting Scholar program provides funds for Los Alamos staff members to do research and related teaching at a University campus or for University faculty to do research at Los Alamos. Research partnership initiatives foster the development of joint research capabilities at campuses that have the potential for external funding and significant research advances. The New Mexico Collaborative Research program was initiated this year, modeled after the CULAR program. Funding for the UCDRD activities, which began in FY 1994, has reached the planned level of about $5 million per year and supports a wide variety of projects, many of which are described elsewhere in this report. The number of projects supported by these funds grew to sixty-three in FY 1997.

Industrial Partnerships

For most of its existence, Los Alamos has partnered with industry to develop technology, generally by paying companies to develop technology and products that were needed to accomplish its mission. In the process, Laboratory scientists helped those companies by assisting in technology development. Before the late 1980s there was neither a mechanism for industry-sponsored research at the Laboratory nor a user facility program. In 1989 the national laboratories, including Los Alamos, were authorized to enter into cooperative research and development agreements (CRADAs), in which the cost of the research was split between the Laboratory and the industry partner.

Los Alamos is the leader in innovative research collaborations between the national laboratories and industry. In 1988 the Superconductivity Pilot Center was established at Los Alamos to meet the scientific challenges and opportunities of the newly discovered high-temperature superconductive materials and to establish mechanisms for developing technologies with industry all the way to commercial application. Since that date the center has engaged in 18 cooperative research agreements, 11 funds-in-sponsored research projects, 6 Los Alamos–sponsored research projects by outside organizations, 2 staff exchanges, and 1 licensing agreement. In addition, 15 patents have been issued, and 14 other disclosures are currently being pursued. The Superconductivity Pilot Center, now called the Superconductivity Technology Center, has illustrated that collaborative research benefits both the DOE mission and industry, while advancing the scientific and technical capabilities of the Los Alamos staff.

The Laboratory's interactions with industry have grown appreciably in the last ten years and now contribute substantially to the Laboratory's mission. The Laboratory has executed 243 CRADAs with a total value of $529 million, 179 funds-in agreements with $71 million in funding to the Laboratory, 147 user facility agreements worth $11 million, and 94 commercial licensing agreements with a royalty income of $1.4 million.

To continue state-of-the-art technology, we must partner with the best in industry to keep Los Alamos at the forefront of science and technology. Partnerships with industry have become an integral part of the Los Alamos way of doing business.

Automotive Applications of Hydrodynamics Codes

The applicability of some computational fluid-dynamics programs is very broad. For example, computer simulations of chemically reactive flows in internal combustion engines and other energy conversion and utilization devices involve complex three-dimensional geometries with moving boundaries, combustion fronts with heat release, and turbulence generation with consequent material mixing and heat transfer. We have developed two computer programs, called KIVA and CHAD, that are widely used in these applications.

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President Clinton inspects the Los Alamos Plasma Source Ion Implantation Chamber during his 1993 visit to the Laboratory.

The KIVA code is based on advanced numerical methods. KIVA simulates the air flow, mixing, combustion, and fuel sprays that occur in many practical combustion devices. The DOE-funded development of KIVA began in the early 1980s, and the code is now mature technology with hundreds of users worldwide, especially among the major automobile manufacturers.

CHAD development was funded by DOE and the automobile industry under a CRADA. The code was conceived as a successor to KIVA for automobile applications, including in-cylinder flows, external aerodynamics, and underhood cooling. CHAD improves upon KIVA in its use of more accurate and flexible numerical methods and in its capability to run on parallel and massively parallel computer platforms. Subsequently, we have found that with some modification CHAD can also simulate shock hydrodynamics and impact dynamics of materials exhibiting anisotropic strength properties. Development of CHAD currently continues both for automobile applications and for some applications in DOE's Accelerated Strategic Computing Initiative. This development is enhanced by the synergy of these two applications.

Plasma Source Ion Implantation

Plasma source ion implantation, an advanced materials process to extend the lifetime of manufactured parts and tools, is another area of joint development with industry. The Los Alamos plasma facility, the largest of its kind in the world, has processed large batches of up to 1000 parts and one-of-a-kind heavy tooling. The program takes advantage of our core competencies in materials, computation, plasma, and beam science. A partner, Northstar Research of Albuquerque, has deployed the first commercial system at a chrome-plating facility in Chicago. We have also formed a vertically integrated consortium consisting of end users, component builders, systems integrators, service providers, research laboratories, and academic institutions to continue this development.

INSTITUTIONAL ISSUES

The Laboratory is supported by the nation's taxpayers, who expect us to do a job and do it well. However, we are also expected to do that job in an efficient and effective manner, with due consideration to the public and the environment, and with a sense of responsibility toward our neighbors. Our work is for the nation, but we also have responsibilities close to home.

First and foremost, the Laboratory must provide a safe working environment for its employees and ensure that they work safely. In addition, the Laboratory's work must not adversely affect the public safety or the environment. In order to do our job, we need to address the condition of the physical plant, many parts of which are almost fifty years old. We must effectively maintain these facilities and ensure their orderly replacement as needed.

Because the Laboratory is publicly funded, we have an obligation to operate cost-effectively. We are using continuous quality improvement to reduce our costs and to be more effective at research and development. At the same time, we must look to the future and ensure that we recruit the next generation of scientists and engineers with full appreciation of the fact that many groups are underrepresented in the science and engineering workforce. Our diversity activities therefore extend to our role in the community. The University's corporate responsibilities include reaching out to the underrepresented groups with educational activities, communicating with the public, and fostering economic development so that the Laboratory's economic dominance in the region is lessened.

HEALTH AND SAFETY

Over the last twelve years, the Laboratory has come to focus on integrating safety in a way that allows greater productivity in our mission-related work, as well as an injury-free workplace. Early on, concern for environment, safety, and health (ES&H) issues was outwardly manifested in such events as the Tiger Team inspection, the creation of the Defense Nuclear Facility Safety Board, the Order Compliance Self-Assessment, and the conversion of certain DOE directives to federal regulations. These activities were not well integrated and caused substantial frustration among our staff. Later, a series of serious accidents caused us to reexamine and reengineer our internal processes to promote and maintain a safe work environment. Although we have made significant progress, we must accomplish much more; full realization of a truly integrated safety culture may take years to achieve.

Our plan is intended to improve underlying safety systems and practices in several ways. We want to institute an integrated safety management program; a more effective safety communication program; a visible, meaningful program of safety performance consequences and rewards; and clear, simple, consistent safety standards and work processes across the Laboratory.

We have adopted the five-step process used throughout the DOE complex to support the establishment, implementation, and assurance of safe work practices.

Five-Step Process for Performing Work

1. Define Scope of Work
   Translate the scope of the project into work.
   Set performance expectations.
   Prioritize tasks and allocate resources.
2. Analyze Hazards
   Identify and analyze the hazards.
   Categorize the hazards.
3. Develop and Implement Controls
   Identify appropriate standards and requirements.
   Identify and implement needed controls to prevent and control hazards.
   Establish a safety envelope.
4. Perform Work
   Confirm operational readiness.
   Perform the work safely.
5. Ensure Performance
   Seek and collect feedback from employees.
   Identify opportunities for improving performance.
   Implement changes to improve performance.
   Reinforce smart work practices.
   Hold employees accountable for their performance.

The five-step process used to ensure that work is performed safely at the Laboratory.

We have developed our integrated safety management program, and at approximately the midpoint in the associated implementation plan, we are on schedule with respect to the milestones. Key goals of this plan include the development of work-smart standards and facility safety plans; improvement of facility authorization bases, safe work practices, and internal assessment processes; enhancement of work planning; continuation of safety awareness and accountability; deployment of ES&H personnel to line organizations; and the piloting of behavior-based safety programs.

We developed a more effective safety communication program; implementation involves fostering a consistent message about integrated safety management values. After assessing behavior-based models in private industry, we began implementing an employee-driven, behavior-based, safety pilot program in one of our major facilities.

With many employees suggesting that the 1996 Safety Days become a regular event, the Laboratory held a second annual Safety Days in July 1997. The second event emphasized the meaning of a safety culture throughout the Laboratory and allowed employees to step back and think about the five steps of our integrated safety management approach to performing work safely.

We began a progressive disciplinary policy for ES&H infractions. It is part of an ES&H accountability matrix that has been in use for one year and has resulted in seventy-one disciplinary actions within the Laboratory and its major contractors. However, we are lagging in developing an appropriate awards program to balance the disciplinary approach.

Currently, we are forming clear, simple, consistent safety standards and work processes from the hierarchy of federal, state, and local laws and regulations; consensus and industrial standards; and DOE technical directives. These work-smart standards, internally known as Laboratory performance requirements will form the basis for performing work safely. We are progressing well and expect these to be fully in place by the end of 1998.

A critical part of the five-step safety process is to provide feedback about the adequacy of controls and continuously identify and implement improvements. To this end, we developed and implemented management safety walk-arounds. This walk-the-spaces program helps line managers to ensure that work they have authorized is being performed safely at the floor level and allows them to effectively communicate safe work practices to workers face-to-face on a regular basis.

It is heartening that during our 1997 Employee Checkpoint Survey, virtually all Laboratory employees reported that they are taking personal responsibility for safety. More important, approximately 90 percent of Laboratory employees believe that management promotes safety in the workplace and takes appropriate action when unsafe working conditions are detected. The Laboratory is thus poised to achieve a truly integrated safety culture where each employee can feel safe in his or her work environment.

Environment

As the Laboratory shifted from internal DOE regulation—the norm in the early 1980s—to regulation by state and federal agencies under national environmental statutes, the complexity of our activities increased substantially, both in meeting regulatory requirements (compliance) and in presenting a credible program of environmental protection to the public. We must meet the rigorous standards of the law, a task made difficult by our previous exemption from that law, and satisfy a number of stakeholders in surrounding communities that we are being responsible in our activities.

The Laboratory provides air-quality monitoring stations like this one to neighboring schools and communities. Information from the network of stations is available on the World Wide Web.

Air Quality

The Laboratory has completed the technical upgrades necessary to bring its radionuclide emissions into compliance with the Clean Air Act under the terms of a Federal Facility Compliance Agreement. As part of the settlement in a citizens suit filed under the Clean Air Act, the Laboratory agreed to allow several independent audits of its program, to hold quarterly public meetings, and to perform some additional environmental air monitoring. The Laboratory also completed an application to the New Mexico Environment Department in order to comply with the Clean Air Act amendments of 1990. Enhancing the quality and timeliness of the reporting of the environmental monitoring of radionuclides in the ambient air around the Laboratory will help to increase public confidence in our stewardship.

Water Quality

The Laboratory has completed construction of a consolidated, sanitary-wastewater treatment plant, which eliminated eight obsolete treatment facilities. We eliminated 150 outfalls, reducing the Laboratory's regulatory exposure to only sixty-six permitted outfalls. An additional thirty to thirty-five permitted outfalls are scheduled for elimination in 1998. The Laboratory has achieved compliance with the limits of the National Pollutant Discharge Elimination System permit at an overall rate of 98 to 99 percent. The Laboratory has received awards from the state of New Mexico and from regional associations for the operation of its wastewater treatment facilities.

Waste Management

In 1989 the state of New Mexico issued the Laboratory a hazardous-waste-management permit. This culminated an extensive period of negotiation with the public and the state regarding mutually acceptable waste management practices at the Laboratory.

After 1990, radioactive and hazardous mixed waste was also regulated in New Mexico. Because of the nature of the Laboratory's research activities, permits were required for numerous mixed-waste-management units. In cooperation with DOE and the state, the Laboratory developed a timely and comprehensive program for the continued use of these units and their incorporation into its Resource Conservation and Recovery Act permit.

Natural Resources

The Laboratory is developing a plan that will integrate natural resources management with other Laboratory planning activities and pull together existing resource-specific plans, including management plans for threatened and endangered species habitat, groundwater protection, watershed, biological resources, fire, and air quality.

Facility Management

Our program for facility management continues to mature. We divided the 43-square-mile Laboratory into a set of distributed facility management units and assessed each unit according to a set of performance requirements addressing a broad range of responsibilities. We are now addressing deficiencies, identified at both the institutional level and the unit level, through corrective action plans. Introduction of a zone maintenance system further strengthens facility management by providing craft support teams dedicated to specific geographic areas of the Laboratory. In addition, a reengineered work control process ensures more rigorous review of work involving hazards to employees.

Facility Revitalization

Because we have such specialized facilities and capabilities and because many Laboratory facilities are old, dating from the 1950s, the need for infrastructure revitalization and facility replacement is significant and will require large, sustained capital expenditures. Up-to-date facilities that meet current standards of construction and operations are essential for our mission and for safe and reliable operations. For example, the Laboratory's existing site-wide intrusion detection and assessment system was installed in the early 1980s. We will soon replace that system, create a new fire alarm–monitoring system, and evaluate options for control of vehicular traffic within the Laboratory. This project will ensure the Laboratory's ability to comply with the security requirements mandated by the future pit-manufacturing role and provide a fire alarm system that meets the requirements of DOE and the National Fire Protection Association.

Our revitalization activity will probably require a minimum of seven years at an average funding level of about $20 million per year. Initially, we will develop the rationale and appropriate documentation for proceeding with needed improvements. It will be necessary to work with DOE to develop cost-effective processes for defining, designing, and constructing capital infrastructure and facilities projects. An effective partnership will lead the Laboratory and DOE to the adoption of appropriate industrial standards and codes.

Site-Wide Environmental Impact Statement

In August 1994 DOE announced its intention to prepare a new site-wide environmental impact statement (EIS) for Los Alamos in order to provide a comprehensive and cumulative look at the environmental impacts of both ongoing Laboratory activities and activities and operations projected for the next five to ten years. The EIS will enable the Laboratory to become a better steward of the environment and will be useful as a planning tool. The Laboratory plays a critical role in the support of the EIS preparation in various ways, for example, by providing data about the Laboratory and reviewing drafts as they are generated. Preparation is delayed, but we expect the EIS to be released in draft form in 1998.

Quality

In 1994 the Laboratory adopted the Malcolm Baldrige National Quality Award Criteria as the standard against which to measure its progress toward becoming world-class in the management of the Laboratory. The criteria were chosen because they allowed the Laboratory to measure itself objectively against the best in leadership, planning, human resource management, management information, customer focus, process management, and bottom-line business results.

Using the Baldrige criteria, the Laboratory assessed itself in 1994, 1995, 1996, and 1997. Through 1996 the results were dramatically positive, demonstrating both commitment and real progress. The first three assessments showed improvements of approximately 100 Baldrige points per year. The 1997 results are not yet available, but preliminary evaluations indicate that our improvement continues.

As a result of the progress in quality, the Laboratory has received recognition in the form of DOE Quality Awards, State of New Mexico Quality Awards, an American Productivity and Quality Center Benchmarking Award, and a Hammer Award. Many Los Alamos management approaches are recognized across the DOE complex and in industry. Los Alamos is now asked to partner in benchmarking activities in both the public and private sectors.

The most direct result of the feedback from the Laboratory's quality assessment process is the selection of institutional quality initiatives. In 1997 we are emphasizing customer focus systems, improving process management approaches, integrating numerous business measurement systems, and continually refining the institutional planning process. As these efforts mature, we are confident that they will eventually equal those of Baldrige Award–winning organizations in the private sector.

Diversity

The Laboratory is committed to furthering diversity in its workforce and continues to support diversity-related initiatives in technology transfer, institutional recruitment, subcontracting, science education outreach, and community involvement and outreach. Several programs illustrate the Laboratory's efforts in those areas. The Diversity Trust, a group dedicated to cultivating and supporting diversity in education and outreach programs, has received approval to begin operations. The trust is a subset of the Laboratory Foundation, which is a nonprofit, philanthropic corporation that provides support to various educational and public service activities in northern New Mexico.

Our internal diversity-related programs are also successful. The Career Development Advisory Council advises management on Laboratory career development issues and defines and addresses the employee-career-planning process. The council has produced a guidebook to aid career development mentors. The Electro-Mechanical Technology Student Training Program, a joint effort involving the Laboratory and the University of New Mexico, trains electromechanical technicians through a combination of college-level courses and on-the-job training with a Laboratory technical mentor.

Corporate Citizenship

For several years the Laboratory has taken major steps to form and strengthen mutually beneficial relationships with its community stakeholders. Significant resources are committed to various programs for community outreach, corporate giving, public involvement, the Bradbury Science Museum, and regional economic development.

Community Outreach

The Laboratory's community outreach programs develop and maintain personal interactions with community stakeholders and leaders. Significantly, we have opened outreach offices in Los Alamos, Taos, Española, and the University of California's Northern New Mexico Office. These offices serve as the focal point for interactions with the community, providing local residents with information and assistance regarding Laboratory operations.

Los Alamos has signed cooperative agreements with the neighboring Indian pueblos of San Ildefonso, Cochiti, Jemez, and Santa Clara. The agreements establish a formal relationship that allows participants to address issues of mutual concern. DOE also has formal agreements, known as accords, with these pueblos. Through the accords DOE has provided funding for environmental programs to assess potential impacts of Laboratory operations.

Educational Outreach

We know that our future success, like the future strength of the nation, depends on a well-educated workforce and a science-literate public. Therefore, the Laboratory and DOE are dedicated to supporting schools by giving teachers and students access to the unique resources of the Laboratory.

Our science education program has grown from a small effort initially supported by indirect funds to a significant, directly funded program with twenty-four projects serving over 2000 participants each year. The projects serve both students and teachers of all grade levels in a wide variety of formats and provide participants with hands-on experiences in science, math, engineering, and technology.

Our extensive efforts to provide undergraduate and graduate students with experience in the sciences are described in this report under "University Partnerships."

Most projects involve the application of technologies such as computer networking and the Internet; some help schools establish their own networks and connection to the Internet. All our projects emphasize the providing of opportunities to students from underrepresented groups. Some projects, such as the Underrepresented Minorities and Females Project and the Historically Black Colleges and Universities Project, specifically target such groups.

Bradbury Science Museum

The Bradbury Science Museum houses exhibits and conducts educational programs about the history of the Laboratory and its research. In 1993 the museum moved from its former location at the Laboratory to downtown Los Alamos. The move generated a closer relationship with the community, a 52-percent increase in annual visitation, and the beginning of a major program of science education and family involvement. The museum expanded its exhibits and initiated a public-dialogue display on nuclear weapons and related issues.

Corporate Philanthropy

In April 1997 the Laboratory launched a foundation to foster and manage financial support of educational and public service activities in northern New Mexico. In addition, through their employees, the Laboratory and the University contributed more than $414,000 to the 1997 United Way campaign. Over the past several years, the Laboratory has awarded $60,000 in scholarships to students from several communities and Indian pueblos in northern New Mexico and has donated $100,000 in sponsorships to various nonprofit organizations in the region.

Teacher workshops sponsored by the Laboratory are a cost-effective means of improving science instruction for many students in local communities.

Public Involvement and Communication

Programs are in place to inform stakeholders about Laboratory activities and provide opportunities to give feedback about these activities. Some major DOE and Laboratory programs that have engaged in the public participation process are Stockpile Stewardship and Management, Laboratory Strategic Planning, APT, and the Site-Wide Environmental Impact Statement.

In the past year the Laboratory has improved communication with its stakeholders and is now making its environmental performance record more accessible to the public. We have held two public meetings to discuss environmental programs at the Laboratory, beginning a regular schedule of quarterly public meetings. We distributed to stakeholders about 1000 copies of our annual Environmental Surveillance Report. The report, which is also available on the World Wide Web, contains monitoring data and summarizes the Laboratory's environmental compliance. In addition, we distributed widely in local communities a separate small booklet, which provides a brief summary of our environmental surveillance program.

Progress in Regional Economic Development

During 1997 the Laboratory, the University, and DOE continued to partner with regional government and business interests to develop new business opportunities that serve the needs of the Laboratory and offer non-Laboratory-based economic opportunities for the private sector in northern New Mexico. We have implemented a new subcontracting approach that encourages key Laboratory subcontractors to invest and leverage their collective fiscal and technical resources in building broader business interests in the region.

Recently, the Fluor-Daniel Corporation set up its northern New Mexico operations for architectural and engineering services for the Laboratory at the city of Española's industrial park in a new city-owned building. Fluor-Daniel expects as many as 150 new jobs for the region and plans extensive local recruiting and hiring to support its activities in the region.

During the year a new support services subcontract was awarded to Johnson Controls Northern New Mexico. In addition to contract services, Johnson Controls will invest corporate funds in the construction of an 11,000-square-foot office complex in the Española Valley, the opening of a recycling project with Nambé Pueblo, and the location of a subsidiary in Los Alamos to conduct energy-saving assessment activities.

The Laboratory has also developed partnerships with Intel, US West, GTE, and other key academic and business leaders in the development of the region's telecommunications infrastructure. This infrastructure will facilitate other partnerships between the Laboratory and regional educational, art, business, and medical organizations to develop Internet capabilities and help build a technically trained regional workforce to support future growth opportunities for the area.

With these successes the Laboratory and the University are fast gaining acceptance within the region as viable and dependable partners in creating a technology-based economic future for northern New Mexico. The strong commitment to these activities by the University and DOE is helping to provide new opportunities for the region.

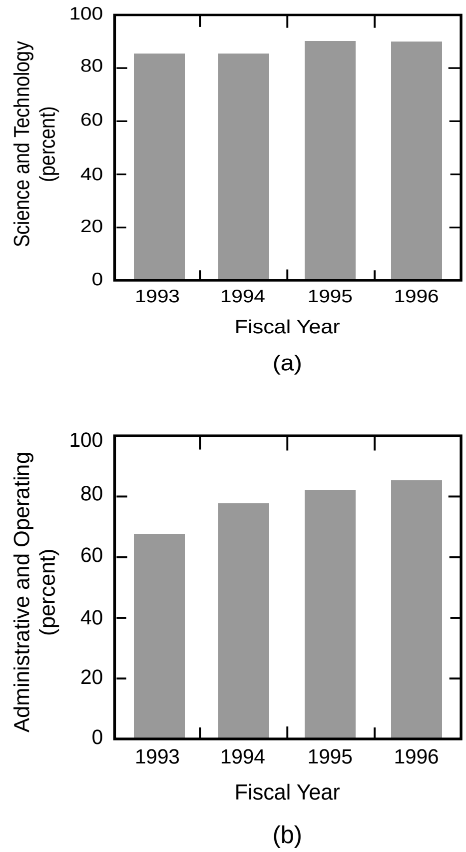
Performance Measures

The contract negotiated in 1992 between the University and DOE introduced the concept of performance-based management to the DOE complex. The performance measures supplemented and enhanced the DOE appraisal of the Laboratory's work by defining objective standards of performance, a self-assessment program, and evaluation of Laboratory performance against the standards.

The performance-based management system outlined in Appendix F of the contract is modified yearly in order to improve the measures and their application to the Laboratory's performance. The Appendix F measures are intended to be the basis for restructuring DOE's oversight of the Laboratory by providing clear, reasonable, objective measures and assessment processes to which the University and DOE agree in advance. These then form the basis of the overall evaluation of the Laboratory in terms of its programmatic (science and technology) and administrative and operational performance. The science and technology assessment is 50 percent of the total score; the Laboratory has ranked consistently well in this area.

The administrative and operating components of the Laboratory's overall evaluation vary as the measures change for the better, but the concept has proved extremely valuable. Indeed, it is a model for the way the government should manage all its large management and operating contracts. For example, when we started this process, our ability to find and account for government property was deplorable. Our score was 45 percent for property management, clearly unsatisfactory. Knowing the trouble and the remedy, we focused our energy on the problem, raising our score first to 73 percent the following year and to 87 and 95 percent in subsequent years. For 1997 our score was 99.89 percent, and we are now the DOE model for property management.

Our property management is a success story, but other outcomes are less positive. However, the lesson we learned is that by paying attention to objective performance measures, not only can we improve, we can excel. Our overall score shows a commendable and steady increase, reflecting our efforts to manage better while simultaneously lowering costs. Through performance-based contracting, we can demonstrate to DOE and the public that we are indeed serving the nation well.



The Laboratory's (a) science and technology score and (b) administrative and operating score under the performance measures of Appendix F of the University of California–DOE contract.

CONCLUSION

"America, indeed the entire democratic world, owes an enormous debt of gratitude to Los Alamos…. When we needed the military muscle to end a global war, the answer was the Manhattan Project. When we needed the muscle to win the Cold War, the long and costly effort to contain and then to triumph over communism, the ideas that made that possible came out of these laboratories."

President Bill Clinton
Los Alamos, New Mexico
May 17, 1993

At the celebration of the fiftieth anniversary of the founding of the Laboratory, Richard Rhodes said to Los Alamos, "So now, fifty years later, fifty years after this city on a hill opened its doors, when we know what the consequences are, I believe the world owes you, and those of your colleagues who are gone now and no longer among us, an immense debt of gratitude." As at the beginning of the nuclear age, I believe we can be proud of the roles our Laboratory and the University have played at the end of the Cold War. Despite the dramatic changes in the international situation, those roles have been consistently positive. We have helped bring about the reduction in tensions that the fall of the Berlin Wall presaged—as Oppenheimer said, "those changes which are needed if there is to be any peace." Today the nation is at peace largely because of the work of this Laboratory. It has been a privilege and an honor to be its director.

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Los Alamos
NATIONAL LABORATORY

Los Alamos, New Mexico 87545